ARMY
STTR 12.A PROPOSAL SUBMISSION INSTRUCTIONS

The United States Army Research Office (ARO) manages the Army's Small Business Technology Transfer (STTR) Program. The following pages list approved topics for the fiscal year 2012 STTR Program. Proposals addressing these areas will be accepted for consideration if they are received no later than the closing date and hour of this solicitation.

Solicitation, topic, and general questions regarding the STTR Program should be addressed according to the DoD portion of this solicitation. For technical questions about the topic during the pre-Solicitation period, contact the Topic Authors listed for each topic in the Solicitation. To obtain answers to technical questions during the formal Solicitation period, visit http://www.dodsbir.net/sitis. For general inquiries or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm EST). Specific questions pertaining to the Army STTR Program should be submitted to:

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The Army anticipates funding one or two STTR Phase I contracts to small businesses with their partner research institutions in each topic area. Awards will be made on the basis of technical evaluations using the criteria contained in this solicitation and the availability of the Army STTR funds. If no proposals within a given area merit support relative to those in other areas, the Army will not award any contracts for that topic. Phase I contracts are limited to a maximum of $100,000 over a period not to exceed six months.

PROPOSAL SUBMISSION

The Army requires your entire proposal to be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Web site (http://www.dodsbir.net/submission). A hardcopy is NOT required and will not be accepted. Hand or electronic signature on the proposal is also NOT required. In this solicitation, Army has established a 20-page limitation for proposals submitted in response to their topics, including the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site and not requiring you to leave blank pages or duplicate the electronically generated cover pages), as well as the Technical Proposal (beginning on page 3, and including, but not limited to: table of contents, pages left blank intentionally by you, references, letters of support, appendices, and all attachments). Therefore, a Technical Proposal of up to 18 pages in length counts towards the overall 20-page limit. ONLY the Cost Proposal and the Company Commercialization Report (CCR) are excluded from the 20-pages.

The DoD SBIR/STTR Proposal Submission system (Available at http://www.dodsbir.net/submission) provides instruction and tutorial for preparation and submission of your proposal. Refer to section 3.0 at the front of this solicitation for detailed instructions on Phase I proposal format. You must include a company Commercialization Report as part of each proposal you submit. If you have not updated your commercialization information in the past year, or need to review a copy of your report, visit the DoD SBIR/STTR Proposal Submission site. Please note that improper handling of the Commercialization Report may result in the proposal being substantially delayed and that information provided may have a direct impact on the review of the proposal. Refer to section 3.5d at the front of this solicitation for detailed instructions on the Company Commercialization Report. Since proposals are required to be submitted in Portable Document Format (PDF), it is the responsibility of those submitting the proposal to ensure any PDF conversion is accurate and does not cause the proposal to exceed the 20-page limit.

When submitting the mandatory Cost Proposal, the Army prefers that small businesses complete the Cost Proposal form on the DoD Submission site, versus submitting within the body of the uploaded proposal. The Army WILL NOT accept any proposals which are not submitted via this site. If the proposal is selected for award, the DoD Component program will contact you for signatures. If you experience problems uploading a proposal, call the DoD Help Desk 1-866-724-7457 (8:00 am to 5:00 pm ET). Selection and non-selection letters will be sent electronically via e-mail.

Any proposal involving the use of Bio Hazard Materials must identify in the Technical Proposal whether the contractor has been certified by the Government to perform Bio Level - I, II or III work.

Companies should plan carefully for research involving animal or human subjects, or requiring access to government resources of any kind. Animal or human research must be based on formal protocols that are reviewed and approved both locally and through the Army's committee process. Resources such as equipment, reagents, samples, data, facilities, troops or recruits, and so forth, must all be arranged carefully. The few months available for a Phase I effort may preclude plans including these elements, unless coordinated before a contract is awarded.

If the offeror proposes to use a foreign national(s) [any person who is NOT a citizen or national of the United States, a lawful permanent resident, or a protected individual as defined by 8 U.S.C. 1324b (a) (3) – refer to Section 2.15 at the front of this solicitation for definitions of "lawful permanent resident" and "protected individual"] as key personnel, they must be clearly identified. For foreign nationals, you must provide technical resumes, country of origin and an explanation of the individual's involvement. Please ensure no Privacy Act information is included in this submittal.

FUNDAMENTAL RESEARCH AND PUBLIC RELEASE OF AWARD INFORMATION

If you collaborate with a university, please highlight the research done by the university and verify that the work is Fundamental Research, defined as basic and applied research ordinarily published and shared broadly within the scientific community.

If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released via the Internet. Therefore, do not include proprietary or classified information in these sections. DoD will not accept classified proposals for the STTR Program. Note also that the DoD website contains data on all past DoD SBIR/STTR Phase I and II awards. This information can be viewed on the DoD SBIR/STTR Awards Search Website at www.dodsbir.net/awards.

PHASE II AND FUNDING INFORMATION

For Phase II, no separate solicitation will be issued and no unsolicited proposals will be accepted. Only those firms that were awarded Phase I contracts, and are successfully executing their Phase I efforts, will be invited to submit a Phase II proposal. The decision to invite a Phase II proposal is based upon the success of the Phase I contract to meet the technical goals of the topic, as well as the overall merit based upon the criteria in section 4.3. DoD is not obligated to make any awards under Phase I or II. DoD is not responsible for any money expended by the proposer before award of any contract. For specifics regarding the evaluation and award of Phase I or II contracts, please read the front section of this solicitation very carefully. Every Phase II proposal will be reviewed for overall merit based upon the criteria in section 4.3 of this solicitation.

Phase II proposals should be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000. Contract structure for the Phase II contract is at the discretion of the Army's Contracting Officer after negotiations with the small business.

Unlike SBIR, the Army does not issue interim or option funding between STTR Phase I and II efforts. However, the Army will provide accelerated Phase II proposal evaluation and contracting for projects that are submitted under the Fast Track Program (see section 4.5 in the DoD 12.A STTR Solicitation). Small businesses participating in the Fast Track program do not require an invitation. Small businesses must submit (1) the Fast Track application by 19 February, 2012 and (2) the Phase II proposal submitted by 19 March, 2012. Army STTR Contracts may be fully funded or funded using options or incremental funding.

CONTRACTOR MANPOWER REPORTING (CMR)

Accounting for Contract Services, otherwise known as Contractor Manpower Reporting (CMR), is a Department of Defense Business Initiative Council (BIC) sponsored program to obtain better visibility of the contractor service workforce. *This reporting requirement applies to all STTR contracts issued by an Army Contracting Office.*

Offerors are instructed to include an estimate for the cost of complying with CMR as part of the cost proposal for Phase I ($100,000 max) and Phase II ($750,000 max), under "CMR Compliance" in Other Direct Costs. This is an estimated total cost (if any) that would be incurred to comply with the CMR requirement. Only proposals that receive an award will be required to deliver CMR reporting (i.e. if the proposal is selected and an award is made, the contract will include a deliverable for CMR.)

To date, there has been a wide range of estimated costs for CMR. While most final negotiated costs have been minimal, there appears to be some higher cost estimates that can often be attributed to misunderstanding the requirement. The Army STTR Program desires for the Government to pay a fair and reasonable price. This technical analysis is intended to help determine this fair and reasonable price for CMR as it applies to STTR contracts.

- The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains the secure CMR System. The CMR Website is located here: https://contractormanpower.army.pentagon.mil/.

- The CMR requirement consists of the following 13 items, which are located within the contract document, the contractor's existing cost accounting system (i.e. estimated direct labor hours, estimated direct labor dollars), or obtained from the contracting officer representative:

    (1) Contracting Office, Contracting Officer, Contracting Officer's Technical Representative;
    (2) Contract number, including task and delivery order number;
    (3) Beginning and ending dates covered by reporting period;
    (4) Contractor name, address, phone number, email address, identity of contractor employee entering data;
    (5) Estimated direct labor hours (including subcontractors);
    (6) Estimated direct labor dollars paid this reporting period (including subcontractors);
    (7) Total payments (including subcontractors);
    (8) Predominant Federal Service Code (FSC) reflecting services provided by contractor (and separate predominate FSC for each subcontractor if different);
    (9) Estimated data collection cost;
    (10) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (The Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information);

(11) Locations where contractor and subcontractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on Website);
(12) Presence of deployment or contingency contract language; and,
(13) Number of contractor and subcontractor employees deployed in theater this reporting period (by country).

- The reporting period will be the period of performance not to exceed 12 months ending September 30 of each government fiscal year and must be reported by 31 October of each calendar year.

- According to the required CMR contract language, the contractor may use a direct XML data transfer to the Contractor Manpower Reporting System database server or fill in the fields on the Government Website. The CMR Website also has a no-cost CMR XML Converter Tool.

- The CMR FAQ explains that a fair and reasonable price for CMR should not exceed 20 hours per contractor. Please note that this charge is PER CONTRACTOR not PER CONTRACT, for an optional one time set up of the XML schema to upload the data to the server from the contractor's payroll systems automatically. This is not a required technical approach for compliance with this requirement, nor is it likely the most economical for small businesses. If this is the chosen approach, the CMR FAQ goes on to explain that this is a ONE TIME CHARGE, and there should be no direct charge for recurring reporting. This would exclude charging for any future Government contract or to charge against the current STTR contract if the one time set up of XML was previously funded in a prior Government contract.

- Given the relatively small size and duration of STTR contracts, and small size of performing companies, the modification of contractor payroll systems for automatic XML data transfer is not in the best interest of the Government. CMR is an annual reporting requirement that can be achieved through multiple means to include manual entry, MS Excel spreadsheet development, or use of the free Government XML converter tool. The annual reporting should take less than a few hours annually by an administrative level employee. Depending on labor rates, we would expect the total annual cost for STTR companies to not exceed $500 annually, or be included in overhead rates.

Army STTR 12.A Topic Index

Army STTR 12.A Topic Descriptions

A12a-T001 TITLE: Passive Wireless Corrosion-Monitoring Tags

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop and demonstrate a passive wireless RFID-like sensor tag system capable of monitoring and detecting corrosive materials and surfaces.

DESCRIPTION: Multiple missile and aviation systems have hidden and/or sealed compartments that can be unintentionally exposed to corrosive environments. Prolonged unchecked exposure to corrosion requires extensive and costly maintenance or rebuilding of the system. Similarly, sealed storage containers housing engines, blades, and other high-value parts at the depot level often remain unchecked for years while seals fail and sensitive components are damaged by water, humidity, and corrosive environments. A long-life low-power small and inexpensive monitoring approach and hardware capability is required capable of continuously monitoring these hidden compartments and storage containers, while allowing maintenance personnel to quickly and easily scan for the onset of corrosion or corrosive environments.

Small passive wireless sensor tags have been proposed as a method of monitoring high-value assets for the onset of corrosion and corrosive environments. Wireless sensors are advantageous in these applications since their data can be transmitted out of the sealed volume. However, powering these devices remains a challenge. A potential approach for meeting power needs is through energy harvesting. Energy harvesting can provide continuous data collection, but there are limited sources of energy to draw from. An alternative approach for monitoring these assets is the application of low-power passive sensor tags similar in nature to RFID-based inventory tracking. An RFID-inspired sensor suite on a small and thin "tag" would be inserted into the compartment or storage can prior to sealing processes. The sensor tag would be scanned by maintenance personnel during routine maintenance activities. The tag would alert the personnel to potential corrosion or corrosive conditions, ideally providing a suite of information including temperature, humidity, and corrosion indicators. The sensor tag system would need to be extremely small so as not to add unnecessary weight to an airframe and to be able to fit within the confines of storage containers and hidden compartments. In addition, reading these devices over long distances and through the walls of sealed containers remains challenging.

PHASE I: Conduct a design study with detailed model development for each component of a passive sensor tag for corrosive environments. Design a reader for the tag system and develop architectures for acquiring data and transmitting to users. The cost to implement the tag reader should be no more than $25. The power consumption by the reader should not exceed 600mW. Demonstrate a proof-of-principle prototype of the proposed tag system. Present cost estimates for manufacturing the sensor tag system. Corrosion metrics such as the distribution and loss of material thickness shall be investigated.

PHASE II: Prototype a series of sensor tags for hidden compartments and storage containers. Prototype a tag reader and demonstrate operation of tags in a relevant depot environment.

PHASE III Dual Use Applications: The achievement of a low-cost passive sensor tags has application to commercial shipping and transportation activities, as well as in the storage and monitoring of commercial vehicles and storage facilities.

REFERENCES:
1) http://www.aginova.com/xcorr_sensor.php

2) http://www.microstrain.com/embed-sense.aspx

3) E. D. Birdsell, J. W. Park, M. G. Allen, "Wireless Ceramic Sensors Operating in High Temperature Environments",

40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 2004, Fort Lauderdale, Florida, AIAA 2004-3990.

4) http://www.rfidjournal.com

5) "Corrosion Monitoring Techniques," http://www.corrosionsource.com/technicallibrary/corrdoctors/Modules/MonitorBasics/Types.htm

6) Paradiso, Joseph and Starner, Thad, "Energy Scavenging for Mobile and Wireless Electronics"http://www.media.mit.edu/resenv/pubs/papers/2005-02-E-HarvestingPervasivePprnt.pdf, Pervasive Computing, Jan-Mar 2005.

7) Birt, E., Jones, L, Nelson, L, and Smith, R, "NDE Corrosion Metrics for Life Prediction of Aircraft Structures," Insight Vol 48, No 3, March 2006.

KEYWORDS: RFID, sensor tag, corrosion sensor, condition-based maintenance

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A12a-T002 TITLE: Formalism for Millimeter-wave Modeling of RADAR Cross Sections

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a physics-based formalism to estimate the RADAR scattering cross section for realistic targets at frequencies from 90-300 GHz.

DESCRIPTION: As interest grows in the development of millimeter-wave (mmw) RADAR techniques for applications such as navigation aides in degraded visual environments, high resolution terminal missile guidance, and detection of wires and small-caliber threats, there is a growing need to understand the RADAR cross sections (RCS) of potential targets and unintentional scatterers (clutter) at mmw wavelengths. The transition from Ka-band to W-band and beyond involves more than just shorter wavelengths and their commensurate technological challenges; it also involves a change in the nature of the scattering problem. Millimeter-sized structures and imperfections significantly change the RCS of objects that would appear smooth at longer wavelengths.

Indeed, it becomes increasingly difficult to separate targets from clutter since both may possess similar scattering features at this scale. Contributions from surface roughness and millimeter-sized features increasingly dominate the RCS of an object, producing a combination of Lambertian and specular scattering. Lambertian scattering from man-made structures may be caused by surface corrugation, abrasion, rust, or corrosion, for example, while Lambertian scattering from terrain, grass, and foliage may also depend on environmental conditions (esp. hygroscopicity and wind). Specular reflection may come from surface imperfections like cracks, dents, fasteners, facets, corners, and edges that act as antennas or retroreflectors in a manner that may or may not be sensitive to the object's orientation and the RADAR's polarization. RCS estimates are complicated by the fact that scattering from many man-made and naturally occurring materials (e.g. composite materials, grass, and foliage) will necessarily include complex, orientation-dependent multipath and interferometric coherent effects involving multiple surfaces at various depths and opacities.

Therefore, estimating the mmw scattering and RCS of an object requires detailed knowledge of an object's geometry, surface characteristics, and the dielectric functions of the constituent materials. The resulting estimates will be an equally complicated function of frequency, polarization, and orientation. What is needed is an academically rigorous framework to guide the modeling of these effects, from which a modeling tool may be developed to provide RCS estimates that may be experimentally validated. The comprehensive modeling framework must establish a formalism for dissecting the scattering problem into the essential constituent pieces, estimate the scattering contribution from each component, then assemble results to predict the RCS of realistic targets and clutter. The tool should focus on frequencies from 90-300 GHz and produce estimates in a manner that can be subjected to experimental validation by polarization-dependent monostatic and bistatic mmw scattering measurements of various targets and clutter.

PHASE I: Develop a formalism to estimate the mmw RCS of realistic objects based on the scattering of constituent components. The formalism must be supported by a first-principles, physics-based approach to estimate the scattering from these constituents and a coherent methodology for combining their contributions in order to estimate the total RCS as a function of frequency, polarization, and orientation. The formalism must (a) consider scattering from simplified smooth geometries (sheet, sphere, cylinder, cone, slot, leaf) composed of various materials (metals, dielectrics, composites, foliage), (b) consider the scattering from roughened (random, fractal, structured) planar surfaces composed of these materials as a function of a characteristic roughening length or scaling parameter, and (c) consider interferometric or multipath contributions from various features and depths of the constituent materials. Proof-of-concept estimations must be provided at the end of Phase I to justify the formalism proposed.

PHASE II: Using this formalism, construct an expandable physics based model that estimates the total RCS for a user-defined target or clutter scatterer based on a set of scattering estimators, a variety of elementary constituent object geometries, and a library of material properties. The tool must have a user-friendly, menu-driven graphical user interface that allows the target or clutter to be "constructed" of the necessary constituents from an expandable library of realistic geometries, materials, and surfaces. Once constructed, the model must allow the RCS to be estimated as a function of frequency, polarization, and orientation. The model must estimate the RCS of individual targets or clutter in a manner that may be experimentally validated, and it must be expandable to address collective scattering effects from multiple identical scatterers (e.g. clutter composed of multiple leaves or blades of grass). The final, user-expandable model and detailed report specifying the methodology used will be delivered to AMRDEC at the end of Phase II.

PHASE III Dual Use Application: Expand the model so that it may estimate the RCS of actual military or civilian targets in the presence of ambient clutter and verify the model's predictions with experimental measurements. The model will allow the construction of realistic geometries using actual material properties to simulate increasingly complex structures such as honey-comb composite materials, suspended wires and cables, rifle bore-scratched .50 caliber rounds, tree canopy, bark, and vegetation containing varying amounts of water moving dynamically in the wind. Ideally, the tool would go beyond simple electrostatic modeling to include transient wave interaction inside the geometries of interest, coherent summation of scattering of multiple geometries, and ground plane interactions.

REFERENCES:
1) K.B. Cooper et al., IEEE Microwave and Wireless Components Letters, Vol. 18, p. 64 (2008). K.B. Cooper et al., IEEE Transactions on Microwave Theory and Techniques, Vol. 56, p. 2771 (2008).

2) W.L. Chan et al., Reports on Progress in Physics, Vol. 70, p. 1325 (2007). W.L. Chan et al., Applied Physics Letters, Vol. 93, p. 121105 (2008).

3) B. Gorshunov et al., International Journal of Infrared and Millimeter Waves, Vol. 26, p. 1217 (2005).

4) J.C. Dickinson et al., Terahertz for Military and Security Applications IV, Proc. Of SPIE, Vol. 6212, p. 62120Q-1 (2006).

5) A. Semenov et al., Terahertz for Military and Security Applications VI, Proc. Of SPIE, Vol. 6949, p. 694902-1 (2006).

6) http://www.saic.com/products/software/xpatch/

KEYWORDS: millimeter wave, RADAR, RADAR cross section

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A12a-T003 TITLE: Real Time 3-D Modeling and Immersive Visualization for Enhanced Soldier Situation Awareness

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop real time 3-D mapping, localization and immersive visualization algorithms and processing technologies to enable seamless and automated real time processing of video and 3-D point cloud data collected from moving air and/or ground platforms and construction of high fidelity, textured, geo-referenced 3-D models of the environment. Demonstrate capability to fully integrate video and point cloud/depth data from multiple sources to provide a globally aligned, consistent and geo-referenced 3-D textured map of the environment with automated detection and alert generation of moving objects and/or stationary objects of interest based on user defined features/characteristics,

DESCRIPTION: Soldiers within the Future Force and those in the current force engaged in combat operations must be able to quickly reduce opposition within urban and complex gps-denied environments while minimizing friendly force casualties. This requires tremendous situational awareness and knowledge of the urban terrain. One of the key technologies required to achieve the required level of situational awareness is the ability to quickly map and visualize the internal and external structures of buildings and automatically identify, classify and track potential threat objects and personnel, and disseminate this data to the small unit leader and soldier as required to support mission execution, rehearsal and after action review. This must be combined with the ability to simultaneously self-locate and construct a textured, 3-D environment map, often in the absence of gps. Solution approaches will require leveraging state-of-the-art advances in high speed graphics computing, 3-D imaging, gaming technologies, augmented/virtual reality display and visualization technologies, as well as fundamental advances in real time 3-D point cloud processing algorithms; registration, alignment and feature matching techniques; loop closure detection; model representation and global alignment techniques to provide a seamless and fully automated end-to-end real time 3-D modeling and immersive visualization of the battlespace. Solution approaches should be modular, open architecture and standards-based to provide maximum flexibility for integration and experimentation with commercially available manned/unmanned platforms and sensor payloads.

PHASE I: Develop algorithm approach and architecture design concept and formulate preliminary development and implementation approach. Develop top level hardware/software (hw/sw) architecture specification, determine measures of performance and demo feasibility of approach.

PHASE II: Develop and demonstrate an integrated functional prototype and operator interface, and validate real time processing performance using COTS sensor payload(s).

PHASE III DUAL USE APPLICATIONS: Algorithms and hw/sw component technology will have broad applications in the areas of commercial robotics, video gaming, modeling and simulation, training, security and law enforcement.

REFERENCES:
1) Peter Henry, Michael Krainin, Evan Herbst, Xiaofeng Ren, Dieter Fox, RGB-D Mapping: Using Depth Cameras for Dense 3D Modeling of Indoor Environment,
http://ils.intel research.net/uploads/papers/henry-RGBD10-RGBD-mapping.pdf

2) G. C. Sharp, S. W. Lee, and D. K. Wehe. ICP registration using invariant features. IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), 24(1):90–102, 2002.

3) S. Thrun, W. Burgard, and D. Fox. A real-time algorithm for mobile robot mapping with applications to multi-robot and 3D mapping. ICRA-2000.

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6) A. Johnson and S. B. Kang. Registration and integration of textured 3-D data. In International Conference on Recent Advances in 3-D Digital Imaging and Modeling (3DIM '97), pages 234-241, May 1997.

7) C. Wu. SiftGPU: A GPU implementation of scale invariant feature transform (SIFT). http://cs.unc.edu/~ccwu/siftgpu, 2007.

KEYWORDS: point cloud, 3-D mapping, visualization, SLAM, texture mapping, real time, geo-registration

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A12a-T004 TITLE: <u>Manufacturing Process Optimization of Ultrasonic Bonding of Metallic Composites</u>

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop and validate multiscale models of the most relevant underlying mechanisms that achieve global properties of ultrasonic bonding during tape placement of metallic composite structures. The overarching objective is to employ such models to the optimization of material, structural, and economic performance of achieved through advanced manufacturing processes. Modeling may include a hybrid of physics based and empirical techniques to pragmatically extend the state of the art of ultrasonic bonding for military and commercial applications.

DESCRIPTION: Recent advances in additive manufacturing are enabling the fabrication of lightweight components with improved capabilities. Armament applications including Army electromagnetic railguns [1] and large caliber guns [2- 4] have benefited from automated fiber composite laying technology to reinforce these high pressure launchers using carbon fiber composites in an organic matrix. Fiber placement is an enabling technology since it eliminates pragmatic constraints of separately jacketed cannon. (E.g., the jacket need not slide over the muzzle which may benefit from a larger outer diameter than the main barrel.) In particular, so called "out of autoclave" composite manufacturing, where the fiber and matrix are bonded as they are laid, are particularly useful to maintain or enhance the desirable residual gun barrel stresses achieved through cold working autofrettage processes. (Consult [5] as a general reference on gun tube design and manufacturing processes.)

However, organic composite armaments are constrained to low operating temperatures relative to mortars, howitzers, and automatic rapid fire cannon. Further, the off-axis properties of organics generally reduce the stiffness of the structures which ultimately may reduce their effectiveness.

Metal matrix composites using lightweight matrix alloys such as aluminum provide excellent cross ply properties including thermal conductivity, modulus, and strength to higher temperature than most organic matrices. Thus, they are applicable to more thermally demanding armaments. Ultrasonic bonding may be employed to bond metal tape during placement to a substrate to form a robust structure. It is most desirable to understand this bonding process to optimize material, structural, and economic performance of full scale manufactured components.

While it is the full scale performance that is of interest, multiscale modeling to better grasp the pertinent phenomena that govern the ultimate global properties is essential. It is worth noting that in addition to the criticality of modeling the manufacturing process itself for component performance at the global scale. Some elements of the operating environment too may require multiscale modeling (e.g., fatigue crack propagation or galvanic effects). Said differently, multiscale modeling of both the manufacturing and the component operating environment may be important.

PHASE I: Develop multiscale model of ultrasonic bonding of a simplified metal matrix tape placement laying process. Determine pertinent modeling scales to derive sufficient knowledge to better understand and improve processing parameters which may include horn design, materials selection, tape dimensions, controlled atmosphere (e.g., noble gas), operating temperatures, etc. Validate to the extent possible (probably through existing literature) models. It is highly desirable that phase I proposals include provision for conducting ultrasonic bonding of metal tape by principle investigators on any commercially available lightweight alloys to ensure traceability of the research to the engineering challenge. It is not essential that high performance materials (e.g., fiber reinforced) are used in recognition of the limited time and resources available to conduct such bonding. Phase I results should include an initial concept of a new or improved ultrasonic bonding process—although the preliminary nature of the concept is understood with an anticipated manufacturing readiness level (MRL [6]) as low as two anticipated.

PHASE II: Extend, revise, or replace the initial concept of a new or improved bonding process to develop and demonstrate an improved manufacturing capability for higher performance materials and structures. It is essential that principle investigators be directly involved in the extensive conduct of experimental ultrasonic bonding in support of Phase II. Although it is desired to produce high performance materials in a laboratory environment (MRL 4) merely the proof of concept may be acceptable (MRL 3) if the cost and performance advance is sufficiently compelling. It is anticipated the multiscale modeling and validation in concert with nonlinear constrained optimization will be essential to the outcome based objective of increased MRL for improved performance materials. Optimization should include both engineering performance outcomes as well as economic considerations through quantitative comparison to alternative approaches through several relevant anecdotal case studies.

PHASE III Dual Use Applications: The topic addresses optimization of manufacturing technology for metal matrix composites to include affordability. Components manufactured of metal matrix materials may be used for any application were the cost justifies the improved performance. Thus, the list of possible dual use applications is extensive as it applies to almost any mechanical component from engine pistons, structural girders, navel hulls, aerospace fuselages, automotive frames, agricultural machinery, consumer products, and sporting equipment to armaments. In general, this technology in phase III will exploit an improvement in the performance to cost ratio for demanding lightweight applications.

REFERENCES:
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KEYWORDS: Additive Manufacturing, Metal Matrix Composite, Fiber-Reinforced Composite, Ultrasonic Welding, Out-Of-Autoclave (OOA) Processes, Prepreg Composite, Association for Manufacturing Technology, Multiscale Modeling, Constrained Nonlinear Optimization, Economic Analysis.

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A12a-T005 TITLE: On Demand Energy Activated Liquid Decontaminants and Cleaning Solutions

TECHNOLOGY AREAS: Chemical/Bio Defense

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this research is to develop a liquid system for immediate decontamination of equipment contaminated with chemical and biological warfare agents using energy activated processes.

DESCRIPTION: U.S. Forces must be prepared to respond rapidly to an attack with chemical or biological warfare agents. A liquid decontaminant that can destroy both chemical and biological threats on the surfaces of tactical vehicles is essential to protect personnel and restore contaminated equipment to operating condition. Use of an organic-based liquid decon product, DS2 (Decontamination Solution 2), was discontinued due to safety and environmental concerns. Despite substantial development effort, no replacement liquid decon product has been fielded. The objective of this work is to develop a chemical and biological decontaminant that is energy activated at point of use thus reducing the logistics burden and significant issues around safety. Ideally the decontaminant can also be used as a general cleaning solution as well.

There is a significant need for a decontamination product that can meet all of the requirements of a practical system. Recent breakthroughs in electrolytic activation of salt solutions have led to promising opportunities for novel decon systems. The product must rapidly destroy both chemical and biological threats, preferably working within 15 minutes. It must be safe for personnel and compatible with the materials encountered on military equipment. A water-based solution is desirable to minimize the flammability hazard. This solution should be active at a pH sufficiently neutral for maximum materials compatibility. The solution must be compatible with the operators' Individual Protective Equipment (IPE) and must not produce any uncontrollable hazards during decontamination operations. The solution must not compromise the function of detectors for chemical or biological agents including M8 paper, M9 tape, the Joint Chemical Agent Detector, the Chemical Agent Monitor, and the Automatic Chemical Agent Detector Alarm.

The ability to prepare the solution on-site is desirable so that only a concentrated form can be shipped, improving the logistics of storage and transport. Many of the existing alternatives using oxidizers are difficult to ship or like enzyme-based systems have issues with pot life stability, operational stability, and shelf-life stability. The solution should mix readily with locally available water, requiring minimal time and effort on the part of the operator and without demanding mechanical mixing equipment. Once mixed the solution should be stable for several days to weeks. Cost must be minimized, and the system should use commercially available components wherever possible.

The solution may be applied with equipment designed specifically for that solution, but it is an advantage if it can be applied with equipment already in inventory. The solution and any equipment required to apply it must be stable for up to 10 years of storage. Previous experience with fielded decon applicators, such as the M11 handheld unit to apply DS2 solution, indicates that there is a substantial burden associated with regular maintenance of a durable, re-usable item: parts must be kept in inventory, personnel must be trained in maintenance and repair of the unit as well as its operation, and scarce manpower must be tied up in maintenance. Therefore it is desirable if the solution and its applicator can optionally be packaged as a single-use item. In this case cost becomes an even more important issue.

Decon performance must be documented not only with surrogates, but also with live CW agents and with spores of Bacillus anthracis (anthrax). Any system sold in the U.S. with antimicrobial claims must be registered with the Environmental Protection Agency under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This requirement is critical for a fielded system, and demands both safety and efficacy data. Therefore, a successful decon solution requires both documentation of efficacy against anthrax spores and complete data on safety, including product chemistry and toxicology that will allow Environmental Protection Agency registration.

PHASE I: Tests and analysis will determine the feasibility of the proposed system. Formulations should demonstrate efficacy against three chemical warfare agent simulants and one live agent, and one biological warfare agent simulant. The decontaminant should remove/neutralize 99.999% of the chemical warfare agent challenge within 5 -15 minutes starting from a 10g/m2 challenge, and demonstrate a 8 log reduction of a 10X8 challenge of a biological warfare agent. Data will be assembled to address materials compatibility, personnel safety, storage, and transport. Formulations should be ready to use within 15 minutes, maintain a minimum pot life of 6 hours following any necessary mixing, and be effective within a range of environmental conditions including temperatures from -25?F to 120?F. Formulations must also have a minimum shelf-life of 5 years and demonstrate stability on storage at elevated temperatures (120?F). Systems analysis will assess the size, weight, and projected cost of the system. Data on sporicidal efficacy and toxicology will be assembled to obtain Environmental Protection Agency registration.

PHASE II: Additional testing and evaluation will be conducted to support a fielded system, including all data to complete application for EPA registration as a sporicidal disinfectant. Formulations should demonstrate > 99.999% destruction of live chemical warfare agents (10 g/m2 challenge), and > 8 log kill of Bacillus anthracis spores (1×108 Colony Forming Units challenge) within 15 minutes. Three different applicator models will be prepared for operational evaluation: handheld, backpack, and cart based.

PHASE III Dual Use Applications: Any additional required testing including testing against live agents will be performed and effectiveness quantified. This technology will have dual use application both by military forces and first responders. Modified versions may have additional application in military or civilian medical facilities to decontaminate pathogens commonly found on surfaces, remediation against mold in buildings, and in cleaning food preparation surfaces.

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KEYWORDS: Decontamination, chemical warfare, biological warfare, sporicide

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A12a-T006 TITLE: Virtual Laboratory of Aggregate Behavior (VLAB)

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: The objective of this STTR is to design, develop and utilize a web based virtual social science experimental laboratory as a platform that will enable randomized controlled trial experiments to be performed on large human groups, enabling hypothesis testing of causal theories of behavior in large groups such as social dilemmas, social mobilization, social network formation, crisis management and public goods problems. The existence of a virtual and persistent social science laboratory will provide researchers with a platform for answering basic questions regarding aggregate behavior and provide planners with a means to pre-test candidate courses of action that impact local communities to reveal the range of responses to these actions, as well as alert planners to second and third order impacts of their actions on local stability.

BACKGROUND: The recent attention of DoD to social issues (Minerva Program and new social programs in the individual OXR's) is required by the asymmetric situations in which defense forces now most often find themselves. However, none of the DoD programs started so far include research investigating how to generalize findings from work on individuals or small groups to aggregates or societies, and how to validate these findings. Controlled repeatable experimentation on large groups is needed to test theories on how large groups of people are likely to respond to changes in their environment. The ability to test theory on aggregate behavior using human subjects provides a means to fabricate essential elements of strategic, tactical, military or commercial situations and experiment with human responses to candidate interventions. Social science theory used today to guide the decisions of military planners is based on a research paradigm that assumes, but is not currently able to test, the relationship between the decisions of hundreds or thousands of individuals and emergent aggregate outcomes. Theory development in areas such as social movements, social network formation, crisis response and public goods problems is achieved through the study of existing social structures and social movements, but it is not possible to directly test theories on how these phenomena form, persist or change using random controlled trial experiments which cannot be systematically repeated on large naturally occurring human groups. While the phenomenon of interest are large (N>1000) groups, most experimental research designed to test these theories is performed on small groups consisting of fewer than 5 participants per group, the findings from which are then generalized to larger groups using logical arguments or mathematical and computational models. The reason for this is that both designing and implementing a meaningful experiment on large groups is very difficult. While the technology exists to allow the simultaneous interaction of thousands of people multiplayer games are not designed to allow the control and manipulation required by an experimental protocol, and those experiments performed on small groups are not designed so that they can be easily scaled to support, let alone attract, sufficient numbers of participants required to be viable. The result is a fundamental research gap. Current approaches assume that behaviors exhibited in small groups scale and can be applied to very large N scenarios. In other words, all currently used computational models of aggregate behavior are based on untested assumptions. Whether or how the behavior of individuals scale as the groups they are a part of grow needs to be better understood and experimentally validated before social theories of mass behavior can reliably describe or forecast real world occurrences. The paucity of work in this area is a result of the challenge inherent in running controlled, repeatable experiments on the interactions of large groups of people.

DESCRIPTION: The goal of VLAB is the design, development and testing of a generalizable web based virtual social science experimental laboratory to facilitate the execution of random control trial experiments that require the real time, simultaneous participation of hundreds or thousands or more of participants. VLAB will provide a stable consistent baseline gaming environment engaging participation in a range of activities representative of types of activities that engage people in real world settings including quests, cooperation and coalition building, conflicts and commerce. In addition, VLAB will be able to support multiple experimental designs and will randomly assign players into experimental conditions (control / treatment) of different sized groups and track the responses of players within different conditions for multiple replications as needed to ensure sufficient statistical power to test hypotheses related to aggregate behavior. The availability of a laboratory of this type will support the direct testing of hypotheses on aggregate behaviors that relates to a range of areas including market behavior, social dilemma, crises response, social mobilization, public goods problems, ethnic conflict and others. The existence of a persistent and consistent baseline environment from which specialized experiments are constructed will also allow comparisons of results across domains allowing for more generalized theory development not possible when research on each topic is idiosyncratically designed so as to not be comparable. More fundamental, it will provide a means to investigate the relationship between individual decision making, group size and aggregate outcomes, providing a means to ascertain if, when and how small group findings can be generalized.

PHASE I: The investigators will design, develop and demonstrate a web-based social science experimental laboratory to support the execution of random control trial experiments on large groups (N>100). Using this environment, researchers will replicate experiments previously performed on small groups to determine whether the findings from earlier work scales or what adjustments in theory are required when group sizes increase. The environment must include 1) a means to automate the orientation of participants to the goals and rules of the experiment and to obtain from each participant informed consent, 2) a cover story or mythology to set the context for the study and engage participants, 3) a means to introduce an experimental treatment, 4) a debriefing instrument and 5) a means to randomize participants into conditions and to collect data to support analyses. During this phase subjects will be recruited by investigators through conventional university recruitment procedures. At the end of Phase I, a working system to support the rapid development of a broad range of large N social science experiments on a range of topics that includes the 5 elements listed above and that has been validated on groups solicited by conventional recruitment procedures will be available. Along with this working system, a plausible path forward to a system (to be created in Phase II) that will not require conventional recruitment procedures but will attract, without excessive bias, players of sufficient number, level and diversity will be presented. The system of Phase I must be based on sociological principles and research standards, not on ad hoc computational procedures or analogies. At the end of Phase I, this system will be evaluated on the ability of the environment to produce valid and reliable results that can be replicated. The technical risk in Phase I include the risk of being unable to create a compelling mythology that supports theory testing. Previous attempts to design experiments in virtual world have demonstrated only marginal success. This is in part because the previously used virtual environment were not designed with experimentation in mind, however, many factors that make a game compelling undermine what is required to make an experiment valid and vice versa. One potential risk is that the project will not succeed in presenting a non-ad-hoc system that represents sociological principles and can test sociological theory. A second risk is in designing a process that generalizes beyond the studied population of available research volunteers.

PHASE II: The investigators expand the system produced in Phase I in the following three ways: 1) Scale the experiments to include more people per group (N>1000). 2) Introduce aspects/features that will attract, without excessive bias, players of very large number, level and diversity to play voluntarily so that conclusions about groups of size N > 1000 can be made (the number of players required for each experiment must be a minimum of 20 times larger than the target size of the group of interest so sufficient replications of each condition can be performed so that statistically valid conclusions can be drawn. 20 times larger assumes two experimental conditions with 10 independent sessions for each condition). 3) Introduce features that will limit or control for the effect of nonsensical and or deliberately deceptive play. In addition to expanding the system, the investigators will use the system to test hypotheses regarding how group size affects the behavior of people in groups and the behavior of large groups under a range of scenarios. The results of these initial experiments will inform the future use of the environment by providing recommendations regarding the numbers of players sufficient to test various types of hypotheses. By the end of phase II the investigators will have developed the capability for large scale rapid development and implementation of very large N (N>1000) random control trial social science experiments. In Phase II, there are inherent risks due to: 1) the lack of prior work on how sociological phenomena scale. Since this will be the first project to run a controlled study on numbers of this size it is possible that increasing the number of participants may have unpredicted effects. 2) A second risk is that the use of a gaming environment to frame the experiment and attract participants may present a bias as participants may not be representative of the general population. Specifically, an oversampling of experienced gamers may introduce types of nonsensical, deceptive or strategic participation not likely in real empirical settings. Specialized models to detect and correct for this behavior will have to be created and/or adapted.

PHASE III DUAL USE APPLICATIONS: The investigators will expand the interface to support the development of valid experiments by non-social scientists such as military planners or private companies. This assumes a persistent web-based social science experimental platform that reliably attracts sufficient numbers of participants (without introducing bias, a major risk factor). This will require a baseline virtual gaming environment that is accessible, compelling and designed with the intention of introducing “interventions” to test experimental hypotheses, but which will persist for entertainment purposes even when no experiments are planned. In addition to providing military planners and industry with a means for pre-testing aggregate behavior, the gaming environment will also fill an elusive gaming industry niche by providing a compelling multiplayer online gaming environment that does not require long term investment by players. Accessibility and persistence is important to attract people to the environment, and refers the requirement that rewarding play not require huge investments of time by participants to gain proficiency. In addition, the game must be compelling so as to be able to attract and retain a sufficient number of participants to support large repeatable experiments. Finally, it will be designed with the intention of supporting experiments across domains and can be utilized by researchers and practitioners in a range of fields including defense, marketing, healthcare, and urban planning.

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KEYWORDS: aggregate, behavior, experiment, game, human, population, social

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A12a-T007 TITLE: Compressive Sampling Video Sensor for Change Detection

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop and demonstrate a hand-held, low cost infrared sensor based on the compressive sampling concept for change detection. The sensor must be able to detect fast moving objects such as rocket-propelled grenades.

DESCRIPTION: Change detection arises in many important military applications such as area monitoring using an unattended sensor network. For an unattended network of video sensors, field operations often require minimum amount of data transition to reduce data processing delay and increase the lifetime of the network. The majority of existing research on sensor-base change detection has focused on data reduction for change detection by post processing the video data to transmit only the change. This approach requires expensive computing at the sensor edge, which likely reduces sensor lifetime for unattended operations. Recent progress in compressive sensing provides a new technique of measuring only necessary data so that sampling is maintained at the minimum just sufficient to recover the needed data by further computational processing later (such as at a central data processing station). The amount of data can be further reduced by a built-in function to separate the change from the background scene. Several sampling schemes including random or knowledge-based sampling have been proposed in the literature with various degrees of computational needs [1-5]. The changes can be stored and summarized for video annotation. Realization of the potential benefits of compressive sampling for change detection requires resolving several challenging issues including reliable algorithms for detecting changes, the speed of sampling for fast moving objects, the limited bandwidth availability, and the implementation on hand-held, low cost hardware.

This STTR topic seeks the development and demonstration of prototype hardware infrared video sensor based on the concept of compressive sampling. The operation scenario may be area monitoring using a network of stationary sensors. The sensor is intended to provide a low cost solution for tracking fast moving objects such as rocket-propelled grenades. It should have a built-in function to automatically separate change from background scene and transmit in real-time the change with resolution dependent of available bandwidth to provide a one-step recovery of a detailed image for any specific event. The size and weight should be comparable with an ordinary smart phone.

PHASE I: Effort may be focused on preliminary design and feasibility demonstration of a dual-band infrared video sensor. Detailed algorithms for compressive sampling scheme and for change detection shall be designed and ready for implementation. Design of the sensor shall be completed, documented, and validated at the component and algorithm level. Potential issues and challenges of further development shall be explicitly identified with detailed plan to address these issues in Phase II. Feasibility of the sensor design should be established so that the design is ready for

Phase II development.

PHASE II: Effort should be focused on prototype development, improvement, and demonstration particularly for detecting fast events with rapid moving objects in a mostly stationary background. The design shall minimize size, weight, and power consumption to ensure a growth path to portability. The prototype sensor should be evaluated and improved to achieve reliable performance under various representative (e.g., urban and open field) scenarios. Tradeoff between image quality and communication bandwidth requirement should be fully investigated, which may require further refinements of sensor design to improve image quality with given bandwidth.

PHASE III Dual Use Applications: Effort should be directed toward hardware and algorithmic refinements to improve performance and robustness for practical remote operations. The goal is to further develop the capability for transition to military programs in C4ISR through defense laboratories such as the Army Night Vision and Electronic Sensors Directorate (NVESD) and/or to commercial defense companies such as FLIR Systems. Commercial applications include homeland security, area monitoring, facility protection, and clinical medical diagnosis.

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KEYWORDS: compressive sampling, infrared, multi-spectral, change detection, fast event detection

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A12a-T008 TITLE: <u>Wide Temperature Range, High-Speed Optical Interconnect Technology</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a military-qualifiable, compact, high speed I/O optical transceiver technology that operates over a -55 C to 125 C temperature range and is suitable for high data-rate chip-to-chip and backplane communications applications. The components should be developed on a low-cost manufacturing platform and be compatible with pick-and-place board level assembly, aka chip-scale packaging, with over 15 Gbps data rate per pin for chip to chip processing (with power levels of 1 mW or more), and 40 Gbps per channel capability (with powers of several mWs) for backplane communications.

DESCRIPTION: High density and high data rate transport infrastructure is required to support sensor read-out and processing in military weapons, surveillance and communications systems. It has well established that photonic interconnects can reduce power consumption and electro-magnetic interference (EMI) associated with driving electronic high data rate signals over copper interconnect. Photonic components that are placed near electronic components reduce the length of the copper signal path. However, for successful adaptation into Army systems, the cost associated with procuring, assembling and operating photonic components must be addressed. Vertical Cavity

Surface Emitting Laser (VCSEL) technology is widely used in the commercial sector for data link less than 300 meters in length at data rates up to 25 Gbps per channel or more, and is therefore the lowest cost laser device for high rate data communications [1-2]. However, current high-speed VCSELs do not function over a wide temperature range. Oxide confined VCSELs are showing limited usefulness in high-speed optical interconnects without significant on-board cooling. New approaches to high-speed wide-temperature range operation are thus sought. Lithographic (oxide-free) VCSELs have shown promise in this regard to the higher thermal conductance across the device [3-4]. Another important consideration for cost reduction is the packaging technology utilized. Chip scale packaging applied to photonic components can create compact and low cost devices [5]. One must also consider that military applications present environmental conditions more extreme than experienced in commercial applications (moisture and chemical exposure, wide temperature operation, shock and vibration, etc).

VCSEL-based transceivers offer multi-channel power-efficient optical communications at high data rates that will be of great interest for the foreseeable future. Current VCSELs are designed to operate in commercial environments, with a limited temperature range. At high temperatures, the VCSEL performance and reliability are degraded. To achieve minimal signal distribution weight and power overhead, the Army seeks innovative research in the area of military qualifiable VCSEL-based transceivers and on-board data links that support high data rate signal transfer rate of over 15 Gbps, operating temperature range between –55 deg C and +125 deg C, optical link margin of 15 dB, operation over multi-mode fiber, and high reliability.

The higher performance integrated photonic components must also meet the following requirements:
1. Package Size: less than 4 mm x 4 mm (PCB footprint) and 4 mm (height, including fiber connector),
2. Assembly: must survive lead-free solder reflow and post reflow aqueous wash,
3. Power consumption maximum of complete backplane transceiver: 100 mW at 40 Gbps,
4. Connectorized components (not a fixed pigtail),
5. Autonomous operation and fully self-contained calibration data for maintaining constant VCSEL output power over temperature.

PHASE I: Demonstrate the feasibility of an VCSEL-based transceiver operating over -55 C to +125 C for pick-and-place assembly near high performance ASICs. Model and simulate a 15 – 40 Gbps per channel compact transmit and receive functions that meet the target requirements. Analyze and model innovative alternatives for packaging for the military environment. Take into account transceiver dynamic range, ease of optoelectronic packaging and manufacturing, needed power levels, and ruggedness. Power levels of approximately 1 mW or more are expected for chip-to-chip level connections and several mWs or more for backplane communications.

PHASE II: Utilizing data from Phase I fabricate prototypes and test a wide temperature transceiver for 25 Gbps data transmission over 50 micron core multi-mode fiber. Demonstrate and measure performance at room temperature and temperature extremes (–55 to +125 ºC). At a minimum, measure the overall power consumption and link margin over temperature range. Develop the assembly process and demonstrate pick-and-place assembly and survival of solder flow processing.

PHASE III Dual Use Applications: Prepare a working design for the operating environment requirements. Prepare and construct enough prototypes to reduce risk of qualification testing. Perform product engineering tasks on the finalized prototypes to support production. Achieve entry criteria for Manufacturing Readiness Level (MRL) 6 accreditation. Address any shortcomings found in pre-qualification testing, update the design and complete final testing. Advance to manufacturing and transition to the appropriate platforms.

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KEYWORDS: Vertical Cavity Surface Emitting Laser (VCSEL), wide temperature range, packaging technology, optical interconnects

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A12a-T009 TITLE: Inferring Social and Psychological Meaning in Social Media

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To develop analytical tools that improve the theoretical relevance, meaning, reliability and validity of data mined and extracted from social media sources.

DESCRIPTION: The mining of social media for various analytical purposes has become ubiquitous in the private sector (e.g., marketing) and across a multitude of government agencies. However, there is an ongoing debate about the reliability, validity and meaning of data mined and collected from social media sources. This is particularly the case for the valid characterization and assessment of the social messaging and social networks of individuals from such social media sources such as Facebook, LinkedIn and Google+ or sights in other cultural settings such as MiGente (Latin America) and Badoo (Europe). Consumers utilize this media for a variety of reasons (e.g., keeping in touch with school mates, communicating with family) that creates variation in the meaning and strength of social ties and just what constitutes an "online community", among other problems. In addition, these inferential problems extend to social media that focuses on message content and special interests (e.g., Twitter, Flixster) that can similarly be conceptualized in social network terms. Some researchers have claimed that reliable and meaningful data can be obtained by separating out the signal from the background noise. However, knowing just what form the signal takes is no simple matter. More importantly, attempts to understand both signal and noise have mostly lacked a clear and well founded theoretical basis for making sense out of patterns found in the data. What is needed is a more theoretically informed approach to the problem that combines well grounded social theory with mathematical theory, graph theory, and computational theory, among others, to produce improved algorithms and analytical tools for the mining of social media. The ability to produce more accurate and theoretically meaningful data obtained from various social media sources will require the identification of a range of social patterns that can be more accurately classified through the use of social theory utilizing both structural (e.g., networks) and non-structural sources of information (e.g., message content, demographic attributes).

These theoretically informed methods can include, but are not limited to: 1) the identification of "online communities" and groups using known theories on the sociological significance of social topologies and network structural motifs, 2) the role of social homophily in estimates of online network formation and in inferring meaning in message content, 3) theories of network closure for estimating social tie meaning and strength, 4) ideas from ego network theory to identify patterns and deviations from normative structural patterns, 5) Bayesian approaches for making inferences and determining information reliability, and 6) qualitative data analytical tools for linking meaning in messaging content with social network characteristics.

PHASE I: Identify the range of theoretically informed methods for the extraction of social media data based on the methods outlined in 1-6 above, as well as other methods not explicitly stated. All methods and potentially relevant algorithms should be identified and documented and clearly linked to their potential uses in corporate (e.g., marketing), military and government applications.

PHASE II: Develop and test prototype set of analytical tools. Test will involve relevant data contexts (e.g., different forms of social media across different cultural contexts) and personnel.

PHASE III DUAL USE APPLICATIONS: Production of software tools that can be used in both military and civilian (e.g., marketing) research and training contexts.

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KEYWORDS: Data mining, data reliability and validity, social theory, social media, social networks

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A12a-T010 TITLE: Development of Low Temperature Ultracapacitor

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop an asymmetric supercapacitor that provides higher energy and power density that current COTS devices, under 10 Wh/kg and ~103 to 104 W/kg respectively, and can be integrated with other energy storage devices, and operates in a wide range of operational temperatures (-55°C to 72°C). Components such as electrode material, electrolyte and separator should be optimized to provide optimal performance of the device. The manufacturing process should be cost effective and easily scalable.

DESCRIPTION: There is a growing need within the Army for electrical storage devices capable of delivering higher power levels, particularly operating at low temperatures (< -45°C) where both COTS batteries and supercapacitors suffer significant performance degradation. Supercapacitors provide high power bursts, have longer cycle life than batteries (over 500,000), but possess low specific energy density, under 10 Wh/kg. At temperatures below -40°C increasing battery electrolyte viscosity and other materials challenges significantly reduce performance. COTS supercapacitors performance is also reduced below -40°C. New supercapacitors with low temperature electrolytes integrated into hybrid power supplies composed of supercapacitors and batteries could lead to substantially enhanced performance and lifetime when operating at low temperatures. Development of such a hybrid power supply is currently limited by the low energy density of COTS supercapacitors, particularly when operating at low temperature. New electrode materials, separators, and electrolyte must be developed and integrated into a device in order to improve performance below -40°C.

This proposal specifically seeks development of a supercapacitor/battery hybrid system that would continuously deliver approximately 50 mA at 3-5 volts and 1-2 Watt, 1-2 second pulses every 10-15 minutes at low temperature (< -45°C).

PHASE I: Develop, evaluate, and validate a button cell asymmetric supercapacitors, operating at low temperature (< -45°C) with the capacity matching current COTS systems operated at room temperature (~10 Wh/kg).

PHASE II: Produce a prototype battery/supercapacitor hybrid system that would continuously deliver approximately 50 mA at 3-5 volts and 1-2 Watt, 1-2 second pulses every 10-15 minutes at low temperature (< -45°C).

PHASE III Dual Use Applications: Increase the capacity (size) and production capability of the supercapacitors. New supercapacitors would likely be used in space and arctic applications were unattended systems are required to operate at low temperatures.

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KEYWORDS: supercapacitor, energy storage, hybrid power

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A12a-T011 TITLE: <u>Nanostructured Electrode Materials for Enhanced Biological Charge Transfer</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop multidimensional nanostructured electrode materials with high surface area that effectively interface with biological materials (e.g., proteins, enzymes) to support enhanced electron transfer.

DESCRIPTION: The Army has wide-ranging needs for portable power. A significant percentage of the total weight carried by soldiers is due to the numerous batteries needed to power portable electronic devices (radios, GPS, etc.). In addition, new applications currently under development, including micro-aerial vehicles, micro-autonomous robots and distributed sensors, are designed for extended mission times and will require strict limitations on energy storage. Biological systems provide significant potential for increased energy density coupled with lower cost through the use of renewable enzymatic biocatalysts and alternative fuel sources (e.g., glucose, ethanol, cellulose). The primary obstacles currently precluding the development and field deployment of enzymatic fuel cells are (i) a lack of effective enzyme immobilization methods to support maximal biological activity, and (ii) limited electron transfer efficiency from the enzyme active site to the electrode surface.

Multidimensional nanostructured materials have recently been explored as novel electrode materials that provide extremely high surface areas. The structural characteristics of these materials are particularly attractive with respect to the current challenges for enzymatic fuel cells. The goal of this topic is to effectively interface biomolecules with nanostructured electrode materials to increase the kinetics of electron transfer from enzyme(s) to the electrode surface.

Enzyme-nanomaterial interface designs should consider maximum biomolecule loading density, engineered interactions between the biomolecules and the nanostructured electrode surface for effective immobilization, and optimal biomolecule organization and distribution within the nanostructured material. Enzyme(s) and fuel source(s) must be consistent with eventual application in an enzymatic fuel cell.

PHASE I: Develop a multidimensional nanostructured electrode material that supports biomolecular immobilization and enzymatic electron transfer. Demonstrate controlled distribution of the biomolecules within the nanostructured material and improved electron transfer kinetics relative to currently published literature.

PHASE II: Optimize the Phase I system and demonstrate controlled distribution and organization of the biomolecules within the nanostructured electrode. Develop an enzymatic fuel cell prototype and demonstrate sustained columbic efficiency greater than 25%.

PHASE III Dual Use Applications: The development of advanced nanostructured electrode materials that support efficient electron transfer in enzymatic fuel cells will support capabilities in soldier portable power, autonomous robotic systems, unattended ground sensors and micro-aerial vehicles. Efficient enzymatic electrodes will also support biosensors for the detection of biological or chemical agents. The development of a cost-effective biological fuel cell that operates on alternative fuel sources will significantly impact the commercial sector by providing an alternative power source for biomedical sensors, food safety monitoring, wireless networks, implantable medical devices and consumer electronics.

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KEYWORDS: enzymatic fuel cell, biomolecule, nanostructured material, electrode, electron transfer

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A12a-T012 TITLE: Mesh Generation and Control for Moving Boundary Problems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop modern numerical methods for mesh generation and dynamic, solution-based adaptivity, and incorporate these into software that can be used in military and commercial simulation software for large scale moving boundary simulations.

DESCRIPTION: High-fidelity modeling and simulation of moving boundary problems with hard and free surfaces continues to be required in a number of important applications. In civilian flood and storm protection and military operations in the littoral zone, more precise modeling of water/air interfaces that can evolve and undergo general topological changes is an important needed capability. The interaction of the interfaces between water/air and solid surfaces is also important and inadequately developed. These surfaces can range from essentially rigid (e.g., ships) to evolving (water waves and eroding beaches). A number of methods have been developed for modeling moving interfaces including volume of fluid [1], front tracking [2] and level sets [3,4]. An important aspect in the accurate development of these methods in large-scale simulations is the construction of effective meshes such that the interface dynamics are accurately simulated. The level of mesh resolution required at the interfaces is substantially higher than needed in the homogeneous portions of the domain where there is a single fluid and the resolution needs to follow the dynamic interface. Accounting for the variable mesh resolution is a requirement to achieve the level of accuracy required, even when massively parallel computing is used. Thus the accurate simulation of these problems requires the availability of highly effective mesh adaptation tools that can evolve the mesh to track the free surface interfaces. New methods for unstructured mesh adaptation are possible in a variety of problems [5,6]. Methods are needed to adaptively create anisotropic meshes at the interfaces defined by level sets [7], and for adaptive mesh control for liquid gas interface problems to track the zero level set interface [8,9]. What is needed under this project is development of these methods in order to achieve a robust capability for modeling free surface problems with a reasonable degree of fidelity that can be employed in military contexts, such as those modeled by the Army Corps of Engineers Coastal and Hydraulics Laboratory (CHL), and commercially. In order to transfer the technology for both military and commercial use, and university researchers and business technical staffs will be involved in both the investigation of the numerical methods and their implementation in software as follows.

PHASE I:
a. Demonstrate the feasibility and develop adaptive mesh control to model free surface problems of interest to both military and commercial waterways modeling applications. In these studies, the free surfaces will be defined in terms of level sets. To ensure compatibility with unstructured mesh solvers, the mesh adaptation procedures should be capable of operating in parallel on distributed meshes that can be dynamically rebalanced as the mesh is evolved. The primary emphasis should be on the core tetrahedral mesh technology, but the design will incorporate other topologies including hexahedral, mixed hexahedral/tetrahedral, and mixed triangular/quadrilateral meshes.
b. Demonstrate at least one method for controlling anisotropic mesh adaptation at level set interfaces.
c. Investigate and determine the tools needed to effectively support automatic mesh generation when input geometry is provided from two sources such as measured natural geometry from Light Detection and Ranging (LiDAR) geometry (e.g., river bed) and designed CAD geometry (e.g., Ship CAD).
d. Develop a verification and validation test set from existing moving boundary simulations implemented in the Army's Proteus toolkit and establish the programming interfaces and software engineering infrastructure required to enhance Proteus with the adaptive meshing capabilities. Proteus will be released to industry and university researchers under an open source license compatible with the commercialization plan.

PHASE II:
a. Perform computer implementation of the algorithms developed in Phase I in coordination with relevant Army scientists.
b. Develop algorithms that generate good initial meshes of systems that can include both natural (e.g., river geometry) and manmade (e.g., ships) for which the geometry may be in the form of surface triangulations and/or CAD models.
c. Integrate the mesh generation and mesh adaptation components with common multiphase flow solvers in Proteus and other common flow solvers.
d. Develop procedures for the a posteriori specification of anisotropic mesh size fields accounting for free surfaces and other interfaces, including any needed control of level set redistancing functions.
e. Develop mesh adaptation procedures that can effectively perform the needed anisotropic mesh modifications, including local solution transfer, to account for the phase interfaces as needed for level set methods and possibly others that may be used for "hard interfaces" like ship hulls which may employ ALE methods.
f. Develop procedures to ensure that all of the above are able to operate on distributed meshes for effective parallel computation.
g. Provide the set of unstructured mesh generation and adaptation tools needed for modeling waterway free surface problems to interested military customers, such as CHL, and market them commercially to firms in the waterways modeling and watercraft modeling industries.

PHASE III DUAL USE COMMERCIALIZATION: Military Applications: Ship motion, wave action, levee/dam breaches, coolant accidents, combustion, oil slicks. Commercial Applications: Same as preceding, plus interests in the off-shore oil industry, pump cavitation, and combustion.

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KEYWORDS: Mesh generation, free boundary, water/air interface, water/ship interface

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A12a-T013 TITLE: Nondestructive Concrete Characterization System

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: Develop a small, portable, low power field device that can estimate the strength and thickness, to 6 feet, of reinforced concrete structures and identify and locate metal contained therein.

DESCRIPTION: Reinforced concrete structures impede the movement of military personnel in a variety of military missions. Non-destructive evaluation (NDE) of the structural characteristics (e.g., material strength, level of reinforcement, thickness) of these structures is important for calculating the amount of charge that must be placed to breach the structure. NDE remains an application requirement in order for missions to remain stealthy. Several techniques have been considered for NDE of reinforced concrete in order to test for defects and deterioration. Techniques such as ultrasound require a transmitter probe that presents short duration high voltage pulses into piezoelectric crystals, and their expansion produces a pressure pulse that administers a broadband field into the concrete. Such systems can be large, require significant power, and are expensive, rendering them impracticable for tactical applications. Conversely, ground penetrating radar is another NDE technique that has also been used extensively to interrogate concrete that may overcome these deficiencies.

While concrete can withstand significant compressive stresses, its tensile strength is approximately an order of magnitude smaller than the compressive strength. Historically, this issue has been addressed by reinforcing concrete with reinforcing bars, rebar, and/or fibers to improve tensile strength. Recent advances in manufacturing high strength concrete mixes, such as those by Lafarge, have rendered current approaches to assessing strength and thickness of concrete (and thus charge size) less accurate. A simple, low power, small and accurate alternative utilizing ground penetrating radar (GPR) technology is sought. GPR has commonly been used for interrogating the ground in a nondestructive fashion in order to assess the presence of objects of interest (landmines, pipes, IEDs) buried below the surface. There are several geophysical companies who utilize GPR for a variety of interrogation applications, including locating rebar in concrete to aid excavation, location of utilities and pipes, forensics and graveyard surveying, etc. The proposed concept for structural assessment of reinforced concrete must operate in a variety of conditions with high accuracy and rapid analysis time. Systems that leverage currently fielded Army systems are preferred, and a detailed proof of concept plan is critical.

PHASE I: Develop the hardware and software design that supports the interrogation technology needed to estimate relevant structural parameters such as reinforced concrete thickness—up to six feet, concrete strength over a range of 3,000 to 30,000 psi, density of reinforcement, and presence of fiber reinforcement. In addition, the approach should be able to locate metal substructure. The approach should demonstrate the ability to estimate these parameters in controlled proof-of-concept experiments with an accuracy of one foot in thickness and +/- 3,000 psi in strength over a variety of structures. In addition, the impact of reinforcement additives such as composite or metallic fiber should be assessed and design issues to address any confounding issues should be put forth. Power consumption and estimated system weight must also be addressed and should be within a factor of two of similar Army deployed equipment. The existence of metal objects should be detected and located to =/- one foot on the wall surface and the density of reinforcement and fiber-reinforcement estimated.

PHASE II: Develop and field test the proposed system for estimating relevant structural parameters and metal substructure. Optimize the design and algorithms for performance, weight, and power consumption. Develop and engineer hardware and software to meet program goals. Conduct field-testing to validate performance on a variety of representative structures to assess accuracy, time-of-measurement, and identify potential operational limitations of the final hardware. Preference should be given to extending the capability of already deployed Army systems to support multiple functions.

PHASE III DUAL USE APPLICATIONS: The proposed technology has potential use in numerous applications within the Department of Defense and the commercial sector. The technology could be used for the Department of Homeland Security as well as state and local authorities, and potentially HAZMAT response teams.

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KEYWORDS: Ground Penetrating Radar, Concrete Characterization, IED Detection, Mine Detection

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A12a-T014 TITLE: High Performance Planar Semiconductor Gas Sensors

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To design, fabricate, and demonstrate a new class of ambient-temperature, high-sensitivity, semiconductor gas-phase sensors for chemical and biological sensing based on the electronic transduction of surface-based probe-target affinity reactions.

DESCRIPTION: The Army has an urgent need for cost-effective sensors for chemical sensing in enclosed ambients requiring time-based analysis such as service indicators. These sensors require tunable sensitivity and selectivity to the analyte of interest and should be operable at the ambient temperatures, i.e. are unheated. Metal-oxide semiconductors have been extensively developed for gas-phase chemical sensors but typically require heating to facilitate the surface chemical interactions required for identifying the analyte(s) of interest and to eliminate the surface hydration layer present below ~ 150°C. [1] Nanowire platforms have shown high sensitivity but present significant manufacturing challenges. [2] InAs and InN planar platforms are highly promising due to their high sensitivity to surface interactions resulting from interactions with their intrinsic near-surface charge layers present as a quasi-two-dimensional electron gas. [3,4] Like nanowire sensors, the sensitivity and dynamic range of these sensors can be tuned by appropriate design establishing operation from accumulation through depletion. To realize the promise of these highly manufacturable technologies, InAs and InN planar sensors will need to be developed with a variety of surface-attached affinity probe molecules inferring selectivity to targets of interest, including NOx, H2O, CO, NH3, and SO2 species. Specifically, it is necessary to fabricate InAs and InN planar structures designed to enhance sensitivity to changes in a known ambient over time periods from weeks to months. Sensitivities from ppt-ppb are required with the dynamic range requirement determined by the monitoring application. InAs and InN devices likely offer differential strengths deriving from differences in their surface charge interactions.

The ultimate goal of this project is to define a new class of electronic gas phase chemical sensors which are highly effective for transducing affinity-probe surface interactions and that are scalable and reproducible. Namely, when produced by available standard semiconductor manufacturing techniques they provide an inexpensive, robust, and sensitive source for DoD environmental monitoring.

PHASE I: In the Phase I effort, a complete designs of chemical sensors based on both InAs and InN planar electronic platforms should be formulated, and the fabrication procedures should be developed for representative device implementations using target-selective metalloporphyrin probe molecules. It is expected that physical attributes such as sensitivities, dynamic range and response and recovery times to NOx species and H2O will be predicted as a function of the material and device structure. The relative performance of InAs and InN devices should be assessed. The Phase I effort should include fabrication experiments and benchmarking that demonstrate an adequate capability for the meeting the expected challenges in fabricating the proposed sensors. Specific milestones include operation to +125 C, > two weeks of continual operation in ambient, and a shelf life of six months. Limits of detection to each target should be in the ppt-ppm range.

PHASE II: In the Phase II effort, a prototypical sensor array based on either the InAs or InN platform, will be fabricated and their ultrahigh detection sensitivity (ppt) to additional targets of interest, including CO, NH3, and SO2 species should be demonstrated. The performances of the sensor should be fully evaluated in terms of sensitivity, selectivity, dynamic range, and limit of detection and should meet the Phase I milestones for NOx and H2O. The project needs to deliver theoretical/experimental results that provide guidance regarding how the sensors can be designed and fabricated for a range of applications with varying sensitivities from ppt to ppm concentrations.

PHASE III DUAL USE APPLICATIONS: The Phase III work will demonstrate scalability and repeatability of the proposed sensors with ultrahigh sensitivity and reliability. Specifically, III-As or III-N devices will be fabricated using standard fabrication technologies and reliability will be assessed using accelerated lifetime tests. This new technology will have commercialization opportunities for such military relevant applications as detection of trace amount chemical, biological and explosive agents. This same technology would find dual-applications such as advanced laboratory components for scientific characterization studies; and materials/process monitoring in commercial manufacturing.

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KEYWORDS: Semiconductor Sensors, Gas Sensors

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A12a-T015 TITLE: Battlefield Ultrasound with Automated Applications

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To develop a compact and rugged, computer-aided (real time and three-dimensional space) ultrasound with related technologies for use by battlefield medics that is capable of automatically detecting collapsed lungs and identifying vascular structure for insertion of central lines and IVs.

DESCRIPTION: The Department of Defense (DoD) has the need for a ruggedized, portable ultrasound system on a compact (iPad/iPhone or similar) platform that will permit battlefield medics to see inside the body. Existing systems require extensive training and skills to interpret and make quick diagnostic decisions (triage and treat). The small screens on smartphones and similar devices make interpretation difficult even for experienced clinicians. This is even harder under battlefield conditions. New compact, ultrasound systems are being developed in the private sector. The DoD seeks to leverage these commercial research investments and pursue the parallel development of automated diagnostic software applications and related devices that are implemented so that minimally trained medics can make improved and faster diagnostic decisions. These automatic algorithms and related technologies should be able to detect collapsed lungs (pneumothorax or PTX) due to blunt trauma, provide displays of vascular structure to support insertion of central lines/IVs, and other diagnostics for use in the battlefield setting.

The computer-aided ultrasound and related technologies must be ruggedized and capable of functioning on a sustained basis in a battlefield setting. The system should be powered by existing, rechargeable Army batteries and capable of continuous operation for one hour without changing batteries. The automated algorithms and applications must be easily employed by medics and diagnostic information must be clearly displayed for rapid interpretation.

PHASE I: Develop a computer-aided ultrasound and related technology system design that meets the stated objectives listed above. Demonstrate a pre-prototype system on a laptop or smaller platform that can automatically detect collapsed lungs and display vascular structure to support insertion of central lines/IVs. Identify additional automated algorithms that can be implemented in the Phase II prototype system.

PHASE II: Develop a prototype computer-aided battlefield medic support system on a ruggedized, portable ultrasound and related technology suite on a compact (iPad/iPhone or similar) platform that will meet the requirements defined above and permit battlefield medics to visualize inside the body. Demonstrate at least five automated algorithms appropriate for use by battlefield medics including the detection of collapsed lungs and vascular displays to support insertion of central lines/IVs.

PHASE III DUAL USE APPLICATIONS: The proposed technology has potential use across the Department of Defense and the commercial sector. It is envisioned that these automated systems will be deployed across the military medic community to aid in the rapid assessment of wounds and accident injuries – thus speeding the delivery of life saving medical response. Similarly, this technology is expected to spin off into the private sector where the compact, automated diagnostic equipment can be used by emergency medical technicians in ambulances to quickly identify life threatening conditions to speed medical stabilization.

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KEYWORDS: Ultrasound, Automated Disgnostics, Collapsed Lung, Imaging

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A12a-T016 TITLE: Non-linear Laser Wave Mixing for Trace Detection of Explosives

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this Army STTR topic is the design and development of a prototype improvised explosive device (IED) detector based on laser-wave mixing using a compact, rugged, solid-state laser-based portable design. The prototype should be able to detect a variety of common explosive vapors present in air at ambient conditions in the part-per-trillion concentration range or lower without the use of additional laser triggers, heaters, or atomizers to pre-excite the explosive chemicals. The device should exploit the coherent properties of the laser-like signal beam created in order to be stand-off capable.

DESCRIPTION: Communications-Electronics RDEC lists “technology to increase the effective on-road speed for detection of surface-laid and buried antitank landmines and in-road IED threats, while maintaining a high probability of detection (Pd) and low false alarm rate (FAR)" as a high priority need. Conventional optical methods, such as Raman scattering and laser-induced breakdown spectroscopy, yield incoherent signals and thus have relatively high detection limits and high FARs in the search for IEDs. This problem is exacerbated due to the very low volatility of many explosive compounds. Laser-wave mixing produces a coherent laser-like signal beam that can be detected with high signal-to-noise ratio in a known beam propagation direction, which leads to orders of magnitude enhancement of detection sensitivity. The wave mixing signal is a time-reversed replica, or phase conjugate of the probe laser beam, and therefore the signal beam becomes more collimated as it travels toward a detector. Laser-wave mixing offers the potential for part-per-trillion or lower sensitivity levels, stand-off detection capability, and real-time nondestructive detection of explosive compounds in their native forms without the use of taggants or sample preparation steps. The nonlinear signal that results has a quadratic dependence on chemical concentration, and should exhibit a very low incidence of FARs.

PHASE I: The Phase I project will design a compact, portable, ultrasensitive detector based on laser-wave mixing for explosive compounds such as triacetone triperoxide (TATP), trinitrotoluene (TNT), and ammonium nitrate (AN) and others. Ideally, this design will include the use of low-power, solid-state compact lasers.

PHASE II: At the end of the Phase II project, the contractor will demonstrate under controlled laboratory conditions a prototype laser-wave mixing IED detector, based on the design from Phase I, that is ultrasensitive (part-per-trillion detection limit or lower) and capable of stand-off detection of explosive compounds at a distance of 15 feet or longer.

PHASE III Dual Use Applications: During Phase III, the contractor will develop the prototype into a rugged, compact IED detector that can be used in the field under expected environmental conditions and at stand-off ranges of 100 feet and longer. The detector is expected to withstand challenging conditions such as heat, sand, vibration, drops, etc. The detector will be portable (no vacuum pumps, no vacuum chambers, no monochromator, etc.) and have reasonable battery life. It is likely that organizations within the DoD such as Special Forces, JIEDDO, and units within the Army and Marines will utilize laser-wave mixing IED detection technology and, it is anticipated that such an IED detector will be useful for other federal, state, and local agencies such as the Department of Homeland Security, the FBI, and HazMat units.

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KEYWORDS: IED, laser-wave mixing, coherent, explosive detection, ultrasensitive, stand-off detection.

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A12a-T017 TITLE: Strain-Modulated Diamond Nanostructures for Next-Generation, Biocompatible Nanoelectromechanical Systems

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design, develop, and demonstrate biocompatible nanoelectromechanical systems and high-Q nanoresonators engineered to exploit intrinsic superior carrier mobility as well as potential strain-enhanced mobility augmentation of single-crystal diamond nanostructures.

DESCRIPTION: The US Army Research Lab maintains strategic research initiatives in next-generation nanoelectronics for unprecedented future light-weight and high performance electronic systems. To this end, the STTR described herein will exploit a host of remarkable intrinsic properties of single-crystal diamond nanostructures (e.g. high mobility, thermal conductivity, and Young's modulus; transparency; negative electron affinity; and biocompatibility) to enable major advances in the foundations of future integrated circuits. Diamond nanostructures may significantly outperform existing silicon, carbon nanotube, graphene, and GaAs electronics technologies in nearly all metrics of interest (electron and hole mobilities, breakdown strength, strain-induced mobility improvements, structural and energetic stability, etc). However, there exist several key challenges that must be overcome and fundamentally understood prior to successful synthesis, integration, and exploitation of single-crystal diamond nanostructures.

One significant challenge involves the synthesis and/or fabrication of single-crystal diamond nanostructures. While polycrystalline and ultra-nanocrystalline diamond has been used as a basis for the fabrication of a variety of diamond electronic and sensing devices, grain boundaries inherent in such forms of diamond impart significant limitations in achievable mobilities and corresponding performance metrics. New methods are needed for the synthesis and/or fabrication of single-crystal nanostructures in order to maximize diamond's potential.

Second, the influence of strain-modulation on the band structure and carrier mobility of diamond demands further basic research. While silicon has been well characterized in terms of effects of lattice strain on band structure and mobility, little is known about these effects in diamond. Likewise, anomalously large spatially-dependent piezoresistivity and the likelihood of flexoelectric responses due to strain-gradients in single-crystal diamond nanostructures require full characterization [1-4]. Appropriate synthesis and experimental testing methods need to be developed alongside theoretical validation to quantitatively ascertain and exploit the sensitivity of diamond nanostructures to surface morphology and crystallographic principal axis direction.

PHASE I: Demonstrate the feasibility of novel diamond-based nanotechnologies via synthesis and/or fabrication of single-crystal diamond nanostructures, and initial demonstration of enhanced electrical and mechanical properties (charge mobility, high Young's modulus and breaking strengths in excess of single-wall carbon nanotubes), compatibility with biological entities, and strain-modulation effects (e.g. piezoresistitivity and flexoelectricity). Review and augment first-principles based models to predict static and dynamic characteristics.

PHASE II: Based on the modeling framework and experimental demonstration in Phase I, optimize synthetic and/or nanofabrication processes and dopant concentration to fully exploit novel properties of single-crystal diamond. Demonstrate electron and hole mobility enhancements due to strain modulation in excess of the highest reported experimental values of 4800 and 3700 cm2 V-1s-1, respectively [5]. Design, build, and test optimized and fully operational foundational high speed and high power nanoelectronics by developing a biocompatible field-effect transistor and high strength nanoresonators. Demonstrate biocompatibility by seamlessly integrating diamond nanostructures with neural networks for monitoring neuronal signal propagation.

PHASE III DUAL USE APPLICATIONS: Development of flexoelectric diamond nanostructures will allow for a broad range of novel device technologies for both the civilian sector and DoD. A major impact on potential applications is anticipated to include, but not limited to, new classes of high strength nanoelectromechanical resonators; high mobility, high thermal conductivity power nanoelectronics (e.g. field-effect transistors); biocompatible sensing capabilities; future UV photonics and field-emission display devices; flexible plastic electronics; and implantable chips for on-body electronics.

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KEYWORDS: single-crystal diamond, field-effect transistor, nanoresonator, buckling, strain-modulation, flexoelectricity

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A12a-T018 TITLE: High Throughput Forensic Palynology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop a system that can automatically analyze materiel containing pollen in order to determine the location of origin of complex samples.

DESCRIPTION: Identifying the origin and recent history of people and materiel is a major technological challenge and critical to the success of current and future operations. There are four major characteristics of pollen that make it particularly informative:
1) Pollen is microscopic, generally ranging from 10-70 um in diameter,
2) Pollen is abundant. Pollen is produced in vast abundance by male plants in order to fertilize female plants of the same species. As most pollen is generally dispersed by either wind or insects, the male plants must produce pollen in vast amounts (up to 100,000 grains of pollen per anther) to ensure that some of it will reach a female of the same species.
3) Pollen is very stable and has been identified in some cases after millions of years.
4) Pollen is exceedingly complex and varies widely from species to species.

This solicitation seeks to exploit the small size, vast numbers, high stability, and diversity of pollen to develop new tools for bioforensics. Specifically this topic seeks to develop a system to automatically identify pollen and analyze pollen composition and to develop a database to link pollen samples to location of origin. It is desirable to create an automated system that can analyze a complex sample of mixed pollen on clothing or other materiel, or in complex substances such as honey, analyze and identify each pollen grain, and then use the aggregate composition of pollen types in the sample to reliably identify the location of origin. The system should be rugged, inexpensive, easy to operate, and highly accurate.

PHASE I: The product of phase I will be the design and demonstration of the feasibility of a system that can reliably examine, identify and classify the spatial and temporal origin of pollen in complex mixtures in an automated high throughput system.

PHASE II: The product of phase II will be a forensics palynology system that can rapidly and accurately analyze complex pollen samples on or in material and rapidly identify the temporal and spatial origin of the sample. The system will include a temporal and spatial database of worldwide pollen distribution that can be expanded and updated by the user. The system will have been tested on blinded samples and both sensitivity and accuracy will be quantified.

PHASE III: The investigators will produce and sell automated forensic palynology systems for use by the Army, DoD, ICE, law enforcement and intelligence agencies.

DUAL USE APPLICATIONS: An automated real-time pollen analysis system would be used by ICE, intelligence agencies, and law enforcement agencies.

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Forensic Sci Int 163(3):163-72.

KEYWORDS: bioforensics, palynology, pollen

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A12a-T019 TITLE: High Quality AlGaN Epitaxial Films with Reduced Surface Dislocation Density

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop device quality AlGaN epitaxial films with reduced surface dislocation density to use them in making high power electric diodes, high electron mobility transistors (HEMTs), RF HEMTs, or blue/UV optical emitters and detectors etc.

DESCRIPTION: Although wurtzite semiconductors (e.g. AlGaN) have the same sp4 bond structure as their zinc blende (e.g. GaAs) counterparts, the dislocation motion in these materials is quite difficult because they have a hexagonal structure. This is a particularly important issue to address for the growth of high quality wurtzite heterostructure films because there almost always is lattice mismatch between the film and substrate that is accommodated by the formation of mismatch dislocations. These dislocations have a negative impact on the properties of the devices fabricated on the films. They can cause premature breakdown in high power devices (1) and gate leakage and reliability problems in RF HEMTs (2), and reduce the luminescence efficiency in optical devices by creating nonradiative recombination pathways(3) and the efficiency of optical detectors by increasing the recombination times (4) etc. Being able to create heterostructure devices enables one to create devices that could otherwise not be made. One such example is the creation of SiGe devices that can operate at higher frequencies than standard silicon devices. These devices have been able to be made to operate effectively and efficiently by learning how to confine the mismatch dislocations to a buffer layer far beneath the film where the active devices are fabricated (5). Now that good quality GaN and AlN single crystal substrates are becoming available, it is important to know how dislocations are formed in the AlGaN films grown on them so one can learn how to confine the dislocations to a layer far below the surface where devices are fabricated much like it is done for the SiGe devices. Unlike GaAs and AlAs, which virtually have the same lattice parameter, they differ by 2.4% for GaN and AlN. Given that the lattice parameters of Si and Ge differ by 3.9%, this challenge should be able to be overcome.

PHASE I: Demonstrate the feasibility to grow epitaxial stoichiometric AlGaN films on GaN or AlN substrates either by MOCVD (metalorganic chemical vapor deposition) or HVPE (Hydride Vapor Phase Epitaxy) methods and demonstrate the evidence of reduction in dislocation density in the top surface layers either by dislocation confinement through the thickness of different buffer layers or other such innovative methods.

PHASE II: Grow devise quality epitaxial AlGaN films with reduced dislocation density (< 10exp6/cm2) near the surface through the optimization of the process developed in Phase 1 experimental efforts and through better theoretical understanding/modeling of the dislocation confinement in the films. The high quality films will be delivered to Army Research Labs (ARL) for evaluation purposes.

PHASE III Dual use applications: The devise quality AlGaN films with reduced dislocation density will be used to make device structures as prescribed by their customers who will likely include those who manufacture high power electronic devices and UV optical emitters and detectors.

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KEYWORDS: MOCVD, HVPE, AlGaN, Epitaxy, HEMT, UV optical emitters anddetectors, dislocations, buffer layers

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A12a-T020 TITLE: Atomic Layer Deposition of Lead Zirconate Titanate Thin Films for PiezoMEMS Applications

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop atomic layer deposition (ALD) of stoichiometric (001) oriented lead zirconate titanate (PZT) thin films with high longitudinal (e33) and transverse (e31) piezoelectric stress constants either with or without Pt templates on patterned silicon substrates. These structures will be used to create piezoelectric actuators for use in RF devices and mm-scale robotics.

DESCRIPTION: As technologies scale to ever decreasing feature sizes, it is becoming important to conserve on mass and volume, particularly in mm-scale robotics. Current design and fabrication approaches are limited to vertical actuation and lateral actuation through mechanical linkages restricted to low aspect ratio structures created using conventional 2-dimensional MEMS processing techniques. The ability to create a true three dimensional (3-D) process to enable high aspect ratio lateral actuators and structures will open up a whole new design space for high density, low power actuators for use in small-scale robotics platforms, biomedical imaging, and communication systems. A limiting factor in realizing these structures is a viable process to deposit high quality, thin film PZT conformal to structures whose sidewalls are oriented in a plane typically perpendicular to (but generally other than) that of the wafer, with maximum PZT piezoelectric response normal to both wafer and sidewall. The first stage of this process, providing underlying growth templates on sidewalls, has been initiated at the U.S. Army Research Laboratory (ARL), and shows promise of feasibility using atomic layer deposited Pt thin films [1]. Chemical Vapor Deposition (CVD) provides thin film growth across a wide range of topography, but is typically limited to shallow features. ALD, on the other hand, while demonstrating isotropic deposition capability into trenches at least 20 micrometers deep for single and binary cation compounds, has undergone limited efforts toward achieving reliable ternary cation compound deposition. The problem is further complicated in PbZrxTi1-xO3 ternary compounds (ABO3 type perovskites) with a mixed solution of B site cations, Zr and Ti, where the choice of proper precursor pulse growth parameters is required for reliable binary stoichiometric growth on B site layers interleaved between A site layers, and each layer type with just the right balance of oxygen.

General precursor development work increases in complexity with the number of chemical elements in the desired final compound [3-4]. The importance of oxygen source is emphasized in Reference [3]. Recent studies of multicomponent ALD-PZT used three ALD precursors to deposit PbO for the A site and TiOx and ZrOx for the binary B site. The results from these efforts have shown that self-limiting growth of ZrOx and TiOx from the Zr and Ti precursors can be achieved, but problems can occur with porosity and Pb-content stability in the deposited film [4-7]. ARL's piezoelectric MEMS (PiezoMEMS) technologies would benefit greatly from uniform, isotropic PZT films that are both dense and conformal to underlying surface features with aspect ratios ranging from 10:1 to 50:1. Figures of merit (FOM) for development may include isotropic self-limiting ALD growth from precursors, stoichiometric growth (Pb/Zr/Ti atomic ratio), pore size limit, density limit, x-ray diffraction (XRD) FOM (including peak position, width, and orientation, Lotgering factor, and rocking curve FWHM), and characterization of nucleation (seasoning) and deposition rate (Arrhenius plots, molar ratios and solution volume), ALD pulse and purge cycle parameters, and oxidation technique and parameters. Overall materials characterization methods may include XRD, atomic force microscopy (AFM), x-ray photoelectron spectroscopy (XPS), wavelength-dispersive x-ray fluorescence (XRF), along with structure analysis by scanning tunneling electron microscope (STEM) of sidewall and overall film depth studied with focused ion beam (FIB), electrical measurements of the dielectric, ferroelectric and piezoelectric response, and any of the above measurements as a function of DC bias and/or temperature.

PHASE I: The offerer will demonstrate the feasibility of depositing high-quality PZT thin films (up to 1 micrometer thick) using atomic layer deposition (ALD) with appropriate precursors, ALD process parameters, stoichiometry control, and thin-film density for technological needs. The offerer will also achieve self-regulated and uniform stoichiometric layer-to-layer growth at a practical deposition temperature with saturated ALD deposition rates to provide dense (non-porous) PZT with controllable Pb content in the A site and Zr/Ti ratio in the B site for PiezoMEMS manufacturing. The offerer will also (1) characterize film quality through XRD by quantifying uniformity of both microscopic and extended device area; (2) achieve uniform 2-dimensional film growth to cover the full area of 100 mm and 150 mm diameter wafers; (3) demonstrate uniformity and c-axis orientation through XRD characterization techniques (for uniform dense PZT films up to 1 micrometer thick); (4) characterize yield and throughput using measurements of the dielectric, ferroelectric, and piezoelectric properties; and (5) report the ALD process characteristics and parameters necessary for successful growth as stated above.

PHASE II: The offerer will map out a strategy of yield development for conformal 3-dimensional (3-D) deposition of PZT with similar uniformity, density, and thickness onto high aerial density structures maximizing c-axis orientation for both sidewall and wafer-plane ALD growth and with practical industrial throughput rates for 100 mm and 150 mm wafers. Targeted metrics should be a dielectric constant of at least 1,000, dielectric loss (tan delta) less than 5%, remnant polarization of at least 20 micro-C/cm2, saturation polarization of at least 40 micro-C/cm2, and a transverse piezoelectric stress constant (e31) of at least 12 C/m2. Phase II will involve depositing PZT films onto 3-D structures, striving to meet the targeted metrics listed above in this paragraph for dense 3-D PZT films with uniform film thickness of 1 micrometer deposited both onto the sidewall of a trench at least 10 micrometers deep and onto in-plane trench bottoms between the sidewalls, striving for high aspect ratios in the range of 10:1 to 50:1. These 3-D depositions should exhibit lateral uniformity over 100 mm and 150 mm diameter wafers and maximize c-axis orientation in both the sidewall and wafer-plane growth directions. Piezoelectric stress constant (e31) should be in the range of 13 C/m2 to 15 C/m2. Choosing suitable techniques, the offerer will strive to characterize using measurements that include dielectric, ferroelectric, and piezoelectric properties: (1) the PZT's structural uniformity and orientation on both the sidewall and wafer-plane and (2) yield and throughput.

PHASE III DUAL USE APPLICATIONS: The offerer will develop and implement benchmarks as needed to meet actual system requirements and documentation to ISO standards of refined, repeatable procedures for a scalable PiezoMEMS manufacturing process for both military and commercial use on a 100 mm and 150 mm wafer fabrication line.

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KEYWORDS: isotropic, self-limiting, atomic layer deposition, precursor, stoichiometric growth, aerial density, isotropic growth, pore size, piezoelectric, nucleation, seasoning, deposition rate, molar ratio, oxidation.

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A12a-T021 TITLE: Sub-Wavelength THz-Frequency Spectrometer for Trace Materials Analysis

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: To develop and demonstrate a terahertz (THz) frequency imaging spectrometer that is capable of providing sub-wavelength spatial resolution at room temperature simultaneously with state-of-the-art sensitivity and spectral resolution when applied to the analysis of small quantities of precisely positioned and controlled biological, chemical or explosive material samples.

DESCRIPTION: There is presently a strong interest in applying very long wavelength spectroscopic-based characterization techniques to threat agent (e.g., biological chemical and explosives) analysis in defense and security scenarios. This interest is motivated by prior fundamental research [1], which suggests that very long wavelength (i.e., in the terahertz frequency regime ~ 0.3 to 3 THz and very far infrared) spectra signatures offers utility for the detection and/or identification of biological, chemical and explosive agents. However, while the THz (and Far-IR) spectral information present within materials/agents has potential use in sensing applications, there are also significant challenges associated with extracting that information from the target samples due to the fact that the spectral signatures: are usually weakly absorbing and limited in total number; can exhibit artifacts and dependencies that are dictated by the microscopic/macroscopic sample geometries; and, are known to be strongly influenced by the external environmental conditions. These general challenges, which are particularly severe for fragile biological materials, have motivated a large number of U.S. Army and DoD programs that focus on improving the state-of-the-art in THz-based sensing science and electronic technology [2]. This includes single-investigator research and developmental (R&D) efforts that are working to improve and extend techniques for the spectral analysis of microscopic samples [3,4] and multidisciplinary R&D teamed efforts that seek to innovate completely new types of nanoscale bio-architectures (i.e., smart materials) with novel transductions for enhancing and multiplying the available spectroscopic signatures [5]. In order for these projects to optimally meet their long-term THz-regime sensing goals such as the spectral-based: monitoring of BW agents; characterization of capture/report recognition-detection mechanisms; and, analysis of synthetic antibodies, receptors and vaccines, a highly accurate and reliable sub-wavelength spectroscopic sensing/imaging capabilities will be required to mitigate the measurement challenges discussed above, and to increase the minimal sample-size of the smart materials that must be analyzed.

Sub-wavelength imaging, even at extremely long wavelengths into the THz regime and beyond, is broadly of interest because it offers the potential for novel interrogations of objects and mechanisms at size scales below the traditional diffraction. While a significant number of near- and far-field techniques have been investigated for optically resolving spatial features that are smaller than the associated radiation-field wavelength (near-field scanning microscopy [6,7], pump-probe microscopy [8], metamaterial [9] and plasmonic [10] super-lens, etc.), all technology demonstrations to date have suffered from limited sensitivity and/or spectral resolution, and in cases where multiple optical fields are employed it is usually difficult interpret the influence of coupling-related artifacts. However, results from very recent theoretical [11,12] and experimental [13,14] research investigations suggest that by combining the advantage of a one-dimensional diffraction-grating type super-lens with a near-field scanning micro-detector that it becomes possible to achieve state-of-the-art spectroscopic characterization (i.e., very high sensitivity and spectral resolution) of biological targets that are wavelength-scale in size and below. Specifically, an optimized periodic grating was used to strongly enhance the THz-frequency transmission and the field-coupling to biological materials contained within a single grating-channel. Scanning (i.e., along the channel) of a micro-detector was then used to successfully measure the THz-absorption at room temperature and to discriminate its variation along the channel. These results are very noteworthy because the room-temperature THz spectroscopy was performed on bio-samples that were less than 1 mm in size (note that the aperture was limited by the size of the detector), but yielded spectral resolutions of less than 1 GHz and sensitivities that were 10 times greater than a fully-optimized THz FTIR system (i.e., and that utilized identical samples 10 times larger). Hence, these technology elements form the basic blueprints for a completely new type of THz microscope, and motivate a new program for integrating it with a sufficient platform (e.g., nanofluidic system) for the precise placement and presentation of the bio-target. Therefore, the ultimate goal of this project is the development of a sub-wavelength THz-frequency spectrometer with state-of-the-art capability for biological materials analysis, and a demonstration of the utility of the system within active U.S. Army research and development programs (e.g., U.S. Army Edgewood Chemical Biological Center) that are focused on advanced sensing and monitoring applications.

PHASE I: In the Phase I effort, a complete design for a sub-wavelength THz-frequency spectrometer with state-of-the-art capability for trace materials analysis should be formulated, and fabrication/integration procedures should be developed for a representative platform implementation that includes a system (e.g., nanofluidic system) for the precise placement and presentation of the target. It is expected that physical modeling will be preformed to assess any influences of the periodic-grating super-lens and the near-field micro-detector on the spectral signatures of the biological, chemical and/or explosive targets. The Phase I effort should include fabrication experiments and benchmarking testing that demonstrate adequate capability for the meeting the expected challenges of integrating the full system.

PHASE II: In the Phase II effort, a prototype sub-wavelength THz-frequency spectrometer should be developed that combines periodic-grating based super-lensing, micro-detector based scanning, and a precise placement and control system (e.g., nanofluidic system or equivalent) to realize state-of-the-art sensitivity and spectral resolution when applied to the analysis of trace material samples. The performance of the sub-wavelength THz-frequency spectrometer should be fully evaluated at room temperature in terms of spatial resolution, spectral resolution, measurement sensitivity as well as the speed and accuracy of materials handling capability. The final system should span the frequency domain of 0.3-1.0 THz and provide a spectral resolution of at least 50 MHz and a spatial resolution of 10 microns. The Phase II demonstrations should also include the implementation and assessment of the spectrometer within an active U.S. Army biological, chemical and/or explosive agent sensing program.

PHASE III DUAL USE APPLICATIONS: The Phase III work will refine the imaging sensitivity and resolution capabilities (spectral and spatial) and optimize the trace materials handling and analysis capabilities. Additional key aspects will be to make the spectrometer user-friendly for performing calibration, collecting spectral signatures, and for interpreting (and correcting) the effects of the super-lens and the micro-detector probe on the analysis results. The sub-wavelength THz-frequency spectrometer is expected to find immediate applications as a detector of biological warfare (BW)agents, and for use in the development of new recognition-detection techniques and in the study and analysis of synthetic antibodies, receptors and vaccines. Therefore, this new technology will have commercialization opportunities for such military relevant applications as detection of BW agents, with obvious extensions to chemical and explosive threats. This same technology would find dual-applications such as advanced laboratory components for scientific characterization studies; materials/process monitoring in commercial manufacturing; and for medical diagnostics and therapeutics.

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KEYWORDS: sub-wavelength, terahertz frequency, spectroscopy, biological, chemical, explosive, materials analysis

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A12a-T022 TITLE: Micro-Machined THz Probes for Electronic Analysis of Integrated Structures

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: To develop micro-machined probe structures that will be effective for precisely characterizing integrated electronic materials, devices and systems up to 1 terahertz (THz) through direct electrical contact. The micro-machined probes envisioned will incorporate a contacting interface for high efficient coupling to the structures under test and a waveguide test port for calibrated connectivity to commercially available terahertz measurement instrumentation.

DESCRIPTION: The standard approach for characterizing materials or devices at THz frequencies is to mount the material sample or device structure into predefined test fixtures based on waveguide housings or quasi-optical structures that permit excitation/interaction with submillimeter radiation. Although this approach is widely accepted, in practice such fixtures introduce significant sources of uncertainty and error in measurements. These errors often dominate the response and are difficult to remove from the data. A superior method is to measure the material of interest in situ, in a controlled environment (e.g., integrated electronic platform) that minimizes artifacts introduced by the measurement instrumentation and allows use of well-characterized standards and calibration procedures to correct for systematic measurement error. Such an approach requires the development of precision probes that are capable of operation at terahertz frequencies and are compatible with the substrate/medium that contains the materials, devices and/or systems of interest, potentially allowing for direct contact and interrogation of the structures that are under test.

The recent demonstration of micro-machined probes for the measurement and characterization of on-wafer devices at terahertz frequencies is a major breakthrough that allows for the first time direct in situ measurement of integrated components at terahertz frequencies without need for separating and fixturing of electronic materials and/or devices. The development of the initial probe prototypes was first reported in [1] where the micro-machined structures were compared in the WR-10 band to conventional probes available commercially. The radio frequency (RF) performance of these micro-machined probes was comparable to that of commercial probes. However a significant advantage is that they are manufactured using silicon micro-machining and lithography. Consequently, non-standard probe geometries can be realized to permit measurement of devices that have unconventional layouts, such as the new class of graphene-based structures or plasmonic terahertz devices currently being researched [2, 3]. Moreover, the probe concept lends itself to scaling and the initial WR-10 design has been successfully redesigned for on-wafer measurements at WR-1.5 (500—750 GHz). Well established calibration methods applied to these scaled probes now permit, for the first time, error-corrected on-wafer scattering parameter measurements over the full WR-1.5 frequency band [4, 5]. Furthermore, the silicon micro-machined probe designs have proven robust and can tolerate over 10,000 repeated contacts before noticeable degradation [6] in RF performance. Because the probe chip is a single drop-in module that is clamped between two halves of a structured housing, replacement of worn or damaged probes is a simple process. Due to these recent advances, the possibility of direct probing and characterization of a wide variety of integrated platforms up to 1 THz, including those incorporating semiconductors, biomaterials and emerging nanomaterials, is now feasible.

The potential of micro-machined THz probes for facilitating the development of novel integrated platforms for such military-relevant applications as sensing, communications and data processing motivate a new program for their optimization and commercialization. Specifically research and development is needed for improving and/or adapting the technology by: scaling beyond the immediate WR-1.5 band to higher frequencies; mitigating the effects of losses in the probe structure to improve dynamic range; and, engineering the probe tips to permit coupling to a wider range of structural media, including microfludic channels or devices with unusual, non-standard and/or nanoscale geometries. Other issues to be addressed including investigation of the probe contact metallization to reduce wear and extend the probe lifetime and the potential of using direct electromagnetic (non-contact) probing for measuring devices that do not require DC contact.

PHASE I: In the Phase I effort, a complete and detailed design will be formulated for a prototype micro-machined probe and waveguide test-port pair that will be operational up to 1 THz. The probe-tip design(s) should be defined so as to be compatible with one or more integrated platforms of relevance, including but not necessarily limited to those containing graphene, plasmonic, and nanofluidic based structures/geometries. It is expected that physical modeling will be preformed (e.g., HFSS, ANSYS, etc.) to assess design trade-offs and the influences of specific substrate medium and materials options, as well to assess the effectiveness of the probes in the context of the expected application (e.g., sensing, data processing, communications). The Phase I effort should include fabrication experiments and benchmarking testing that demonstrate adequate capability for the meeting the expected challenges associated with analyzing integrated materials, devices and/or systems during a potential Phase II effort.

PHASE II: In the Phase II effort, a prototype micro-machined THz probe system will be developed, implemented for operation in the range 0.3 to 1.0 THz, and demonstrated for its effectiveness in analyzing and characterizing one or more integrated electronic platforms (e.g., graphene, plasmonic, and/or nanofluidic based structures). Platforms should be chosen that have direct relevance to military applications. It is minimally expected that the micro-machined THz probe and waveguide test-port be applied to perform electrical analyze small (micron to nanscale) materials samples contained within an integrated electronic platform. It is also strongly encouraged that demonstrations be defined and executed that will have relevance to biological chemical and/or explosive sensing and that they be coordinated with the U.S. Army Edgewood Chemical Biological Center, or some other appropriate DoD Laboratory.

PHASE III DUAL USE APPLICATIONS: The Phase III work will refine the micro-machined THz probe system to improve performance, reliability and it adaptability to varying types of integrated electronic platforms and associated targets. Additional key aspects will be to make the THz probe system user-friendly for performing calibration and for interpreting electrical characterization data. This THz probe system should find immediate application as a characterization and development tool for new types of very high frequency integrated electronic platforms, e.g., such as those employ graphene, plasmonic structures and nanofludic channels. Hence, THz probe system would find commercialization opportunities across a wide spectrum electronic component development for sensing, data processing and communication applications. This same THz analysis tool would also be immediately relevant for sensing trace quantities of biological, chemical and explosive agents, and could be evolved into a separate sensor system for military warning, industrial monitoring medical diagnostics.

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KEYWORDS: micro-machined, terahertz frequency, probes, integrated platforms, graphene, plasmonics, nanofluidics,

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A12a-T023 TITLE: Narrowband Perfect Absorber for Infrared Sensing.

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a Narrowband perfect absorber that is designed to operate with a thermal infrared detector array for the detection and identification of toxic industrial chemicals and chemical agents.

DESCRIPTION: The chemical and biological defense community has the need for a small lightweight sensor for detection of toxic industrial chemicals and chemical agents. Infrared absorption spectroscopy has proven to be a very useful tool in the detection and identification of airborne chemicals. Pattern recognition is used to compare the infrared spectrum of library molecules against the infrared spectra of airborne contaminants.

Infrared thermal detectors, such as microbolometers, thermopiles, and ferroelectrics, hold the potential for significantly improving the chemical and biological sensing capabilities of the DoD. Thermal detectors are typically broadband detectors. Individual pixels absorb light across the entire infrared region, generating a thermal image. Currently available broadband uncooled thermal detector arrays, such as the latest generation of microbolometer arrays, are not sensitive enough to perform low-concentration chemical detection. In particular, microbolometer arrays operating in the longwave infrared region (~ 8-12μm) are limited by the blackbody radiation limit.

The blackbody radiation limit only truly applies to broadband devices detecting radiation in the long-wave infrared (~ 8-12μm). The potential performance limit of uncooled thermal detectors is beyond the blackbody radiation limit. To date there has been very little research work in wavelength-selective uncooled devices. However, the initial studies have shown that a narrowband uncooled array could have significant improvements in sensitivity approaching the sensitivity of cooled infrared devices.

Metamaterials can be characterized by a complex electric permittivity and magnetic permeability. Much of the work in metamaterials has focused on the real part of electric permittivity and magnetic permeability, which can be manipulated to form a material with a negative index of refraction. However, the imaginary part of the electric permittivity and magnetic permeability can also be manipulated to create unusual properties. In particular, the electric permittivity and magnetic permeability of metamaterials can be manipulated to create a very strong absorber. By manipulating electric and magnetic resonances independently, it is possible to absorb both the incident electric and magnetic field. Additionally, by adjusting the electric permittivity and magnetic permeability, a metamaterial can be impedance-matched to free space, minimizing reflectivity. The use of perfect absorbers may provide a method of exceeding the blackbody radiation limit imposed by most current uncooled thermal detectors. The ability to reject out-of-band noise by only allowing absorption over a small frequency range may provide for sensitivities that approach current cryogenically cooled photodetectors.

Considerable research has gone into developing perfect absorbers with a wide angle of acceptance. For spectroscopic applications a narrow field-of-view may be preferable. Self-radiance is a problem that must be addressed when designing infrared sensors. The infrared detector or focal-plane-array detects radiation emitted from the inside of the sensor from various surfaces. Self-radiance is often controlled with the use of cold-shields within the instrument. However, the use of cold-shields introduces cyrogenics, which increases size, weight, and power requirements. A perfect absorber that only absorbs radiation that enters from normal incidence with a small acceptance angle may allow for the elimination of cold-shields within an infrared sensor. The acceptance angle depends on the sensor design, but it should be small enough to eliminate the need for cold shields.

PHASE I: Design narrowband perfect absorber that operates in the 8-12μm region of the infrared spectrum. The perfect absorber should be suitable for use in a thermal detector. In particular the narrowband absorber should be fabricated as a thin film with low thermal mass. The perfect absorber should absorb infrared radiation over a small spectral band of approximately 0.1 μm. Infrared radiation outside of this spectral region should be either reflected or transmitted through the material without absorption. The perfect absorber should be designed to absorb only radiation that enters at normal incidence to the surface of the detector. For this study an acceptance angle of 20 degrees should be used (10 degrees plus/minus from normal incidence)

PHASE II: Fabricate narrowband thermal detectors pixels suitable for chemical sensing. For this application a series of pixels operating at different wavelengths may be used. Thermal detectors of any sort (bolometer, thermopile, ferroelectric, liquid crystal) may be used. The pixels should span the 8-12μm region of the infrared spectrum with a resolution of approximately 0.1 μm. The pixels should absorb only the infrared radiation that enters from normal incidence. Off-axis infrared radiation should be reflected or transmitted through the perfect absorber. Characterize the detectors in terms of sensitivity and noise. Examine the utility of using infrared perfect absorbers for infrared sensing applications. In particular examine the utility of these devices in chemical sensing.

PHASE III DUAL USE APPLICATIONS: Further research and development during Phase III efforts will be directed towards refining a final deployable design, incorporating design modifications based on results from tests conducted during Phase II, and improving engineering/form-factors, equipment hardening, and manufacturability designs to meet U.S. Army CONOPS and end-user requirements. There are environmental applications for a small robust, chemical sensor. A rugged, inexpensive chemical sensor will benefit the manufacturing community by providing inexpensive monitoring of chemical processes. Also, first responders such as Civilian Support Teams and Fire Departments have a critical need for a rugged, inexpensive sensor that can be transported to the field to test for possible contamination by CW agents.

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KEYWORDS: chemical detection, infrared spectrum, thermal detector, metamaterials, perfect absorber, electric permittivity, magnetic permeability.

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A12a-T024 TITLE: Engineering and Development of Anisotropic Conductive Polymer Nanomaterials for Visible, Infrared and Bi-Spectral Obscurant Applications

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop electrically conductive, polymer materials for obscuration applications. By physically engineering (shape and conductive properties), absorption and reflective properties can be optimized to interact with EM areas of military interest. Specific regions of interest include Visible (0.4 to 0.7um), Near Infrared (0.7-1.0um), Mid Infrared (3.0 – 5.0um) Far Infrared (8.-12um) and millimeter/microwave (140 - 3gHz). Highly conductive flakes / fibers as well as highly reflective spherical materials to reduce electromagnetic (EM) transmissions are very desirable for next generation obscurants. Nonmetal materials that can offer both properties are needed to cover a broader range of the electromagnetic spectrum.

DESCRIPTION: Obscurant materials are used by the Army to protect both the soldier as well as military physical assets. Several obscuration systems have been developed over the years to defect threats in all areas of the electromagnetic (EM) spectrum. Historically, work has focused on millimeter and microwave, infrared (IR) and visible (VIS) regions individually, with the goal of reducing signal signatures to defeat or confuse smart sensors. With the emergence of new threats and sensors, requirements have been established for multi-spectral devices to defeat all types of threats concurrently, using novel, lightweight and highly performing obscurants. The desire for environmentally friendly materials as well as non-hazardous to human life have pushed the need for new, non-metal but highly conductive obscurant materials. Polymers are well adapted for novel engineering techniques to precisely control their physical properties. Controlling the shapes of these electrically conductive polymers by producing spheres, platelets and rods, will all contribute to reducing the visible acquisition and electronic targeting of military assets and personal. Classical physics and theory have shown that spherical materials with a large index of refraction are most efficient scatters for visible EM regions. Also, thin platelet materials with a large conductivity are most efficient absorbers for IR regions. Novel materials having high conductivity and high indices of refraction are well suited for next generation of obscurant materials.

PHASE I: Develop and synthesize highly conductive polymer materials with conductivities equal to or greater than that of iron (>=1.044 X 107 Siemens/m). Ideally, the conductive material will have an index of refraction in the visible region similar to Rutile TiO2. Starting with flake shapes for IR obscurants, develop novel process and methodologies to produce 5-10 grams of infrared obscurant to be tested at Edgewood Chemical and Biological Command (ECBC) test chamber. Using modeling theories, determine the electromagnetic wave interaction of the flakes to optimize their attenuation and scattering efficiency. The primary focus of this effort is to provide proof of concept that these materials can provide an effective obscurant that can compete with already existing materials. Cost analysis of the scalability of these processes should also be addressed. In process testing can be performed at ECBC at no cost to the contractor. For small sample testing, ECBC recommends Nujol technique for wet suspension and DPT measurements for dry materials. ECBC personal will be available to assist contractor in setting up testing guidelines.

PHASE II: Develop novel process and methodologies to form other shapes of conductive polymers for visual, infrared and millimeter/microwave regions of obscurant interests. Model electromagnetic wave interaction of these shapes to determine how different configurations effect scattering and absorption of incident electromagnetic waves. Optimize shapes for specific regions of military interests to maximize signal reduction in other areas besides infrared. Investigate mixing of shapes for enhancing dispersion and packing as well as covering a broader range of the EM spectrum. A testing matrix should be developed to determine optimized mixtures of shapes that can attenuate specific regions. Continue with cost effective scale up material development and fabrication, developing processes that will produce enough materials to fabricate several full size hand grenades based of the M106 geometries. The 2nd part of this effort should concentrate on developing novel ways to aerosolize materials developed in Phase I and Phase II. Several concepts should be investigated to effectively pack and disseminate polymers with heat generating devices like center buster explosives. However, if this is not feasible due to deleterious effects of explosives on polymer materials, pneumatic alternatives should be considered. Strategies to increase packing fractions and device yields will improve overall obscurant systems performance and reduce logistics burden.

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KEYWORDS: Conductive Polymer Nanomaterials, Obscurants

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A12a-T025 TITLE: Preserving Navigation Access for the War Fighter – Development of an Acoustic Marine Life Watch System to Support Corps Channel Maintenance and Enhancement

Activities

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this effort is to design and demonstrate an active acoustic-based sensor system to detect, track, and classify large aquatic animals in the immediate vicinity of Corps channel maintenance facilities and operations. This effort is needed to assure critical assess to navigation channels by Department of Defense (DoD) war fighters. System should be configurable to detect, classify and alert to the presence of threatened and endangered (T&E) marine animals and marine mammals, including, but not limited to, manatees, sea turtles, sturgeon, and dolphins, at a user selectable range of as much a 125 meters. System should be rapidly deployable to attach to a barge or bulkhead and be operable by a single trained technician.

DESCRIPTION: While activities of the U.S. Army Corps of Engineers to maintain and enhance navigation channels are primarily thought to benefit commerce and recreation, they are vital to national security by supporting the war fighting activities of the DoD. Specifically, navigation channels in Chesapeake Bay; Norfolk, VA; Charleston, SC; King's Bay, GA; Mayport, FL; Corpus Christi, TX are directly used by war fighters enroute to conflicts, and additionally, channels at Charleston, SC; Port Canaveral, FL; Beaumont, TX are used for Army warfighting materiel transport (Surface Deployment and Distribution Command). Any risk to keeping channels open and fully functional represents a threat to national security. One such risk is posed by the requirements of the Endangered Species Act (ESA) of 1973 and the Marine Mammal Protection Act (MMPA) of 1972. These mandate that no threatened or endangered (T&E) species or marine mammal be "taken" by any federal activity, such as dredging or channel improvement. "Taken" is defined to mean to kill, injure, or harass.

Within the continental United States animals covered by ESA and MMPA that frequently occur in Corps navigation projects include 6 of the 9 species of sturgeon in North America, 5 species of sea turtles, the Florida manatee, and dolphins. In terms of geography these species are found from the upper mid-Atlantic coast, south to Florida and throughout the entire Gulf of Mexico. An example of the potential threat of these laws to Corps channel maintenance activities is evident in a recent mandate by the US Fish and Wildlife Service (FWS, agency charged with enforcing these laws). FWS and Florida resource agencies found the Corps watch program for manatees near operating bucket dredges to be inadequate and required that a significantly enhanced automated technique be developed in 2 years or they would remove their approval for Corps dredging activities at night. Such a restriction would half the dredging capacity at manatee sites (Port Canaveral, FL, in particular). It is expected that such restrictions will soon be applied to additional species including sea turtles. This is a significant and eminent threat to the Corps ability to keep channels open and operating at design capacity.

An active underwater acoustic system is required that provides rapid updating (>1 Hz) to detect potential targets entering a full circle of a user-specified distance (<125 m). At this detection limit the entire water column (up to 15 m) would be monitored. Detected objects in or entering this circle would be tracked and classified (using the same or a different active acoustic sensor system) as being one of several classes of interest, such as manatees, sea turtles, or other T&E species, or objects not of interest, such as schools of fish or boats. When an object classified as a target of interest comes within a second, closer user-specified distance, a real- time automated warning signal would be sent to the pilot house or operator to suspend operations until the animal clears the area. The system must be able to digitally archive all detections, tracking, classification, and alerts generated. The system must be portable and rapidly deployable on a mobile (barge or ship) or fixed (dock or bulkhead) platform, and operable by a single trained technician. It must be configurable for various animals of interest and operations, such as dredging or blasting. The technical feasibility of manatee detection using active acoustics has been demonstrated (Jaffe et al. 2007).

PHASE I: Develop design of an active acoustic system that will perform the functional requirements described above. It must be shown that this design will function in a broad range of natural environmental conditions, such as salinity, temperature, suspended solids, current flow, migration of non-target animals, etc., and conditions induced by the Corps operation, such as water column bubbles from bucket dredge, and short periods of excessively high suspended solids concentrations. One data collection opportunity can be provided on an operating Corps bucket dredge, and boat access can be provided to collect data in an area with high populations of manatees.

PHASE II: Based upon the design developed in Phase I, develop and field demonstrate, under operational conditions, a prototype system capable of:
1. Continually detecting surrogate acoustic targets during at the required detection range in the presence of an operating bucket dredge.

2. Achieving a 95% detection rate with 90% classification accuracy for manatees at specified operating ranges relative to trained manatee observers.
3. Achieving a false alarm rejection rate of at least 90%, based on observations of trainer observers.

PHASE III Dual Use Applications: Development of commercial system for installation on Corps physical plant for monitoring of T&E species during operations.

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KEYWORDS: acoustic sensors, sonar, marine mammals, threatened and endangered species

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A12a-T026 TITLE: Industrial Production Methods for Ultra-High-Strength Carbon Nanotube-Based Fibers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Development of viable, cost-effective, industrial production techniques for carbon nanotube-based fibers with low density and ultra-high strength and toughness.

DESCRIPTION: The mechanical properties of carbon nanotubes (CNTs) such as low density, high stiffness, and exceptional strength make them ideal candidates for high-strength fibers, fabrics, and reinforcement material in a wide range of high-performance composites. While the strength and stiffness of CNTs are extremely high, to date CNT fibers have been found to be far weaker than the constituent CNTs. There is evidence that slippage between overlapping CNTs occurs in CNT fibers under strain and that the slippage occurs at tensions well below the breaking strength of the CNTs.[1–5] Twisting and stretching the individual strands into a fiber has been demonstrated to increase the load transfer between the CNTs and result in higher elastic modulus and strength.[1, 2, 5–10] However, the tensile strength of the twisted fibers is still considerably less than the tensile strength of the constituent CNTs.

Simulations and experiments indicate that the factor limiting the strength of the CNT fibers is the poor load transfer between the CNTs. This poor load transfer between CNTs limits the mechanical strength and moduli of CNT fibers. The implication is that in order to achieve the tensile strength in an arbitrary length fiber equivalent to the tensile strength of the constituent CNTs, load transfer between the CNTs will need to be enhanced. Such enhancement may come in many forms, and could include the twisting of the fiber as discussed in Qian et al.[11]; cross-linking of the CNTs through chemical bonds as discussed in Frankland et al.[12], Kis et al.[13], Cornwell et al. [14], Filleter et al. [15], and Cornwell and Welch [16,17]; or entanglement of the CNTs. Ultimately, the ability to produce CNT fibers with a minimum number of defects while optimizing the load transfer through twisting, entanglement, and/or chemical bonds will play a major role in determining the mechanical properties of CNT fibers.

The challenge for nanomanufacturing is to develop processing techniques that create specific nanostructures that lead to the desired material properties. This proposal is seeking a CNT fiber manufacturing technique for the cost-effective mass production of CNT fibers with ultra-high-strength and toughness properties that exceed those currently available in high-strength fibers.

PHASE I: Develop novel CNT fiber designs and innovative manufacturing technologies to fabricate a lightweight, ultra-high-strength, flexible CNT based material. The objective is to increase the strength, flexibility, and toughness beyond those of current high strength materials. It should be demonstrated that the manufacturing process is capable of scaling to mass-producing the ultra-high-strength fibers. Samples of the fibers and fabrics will be delivered along with a detailed report of the development and testing of the new high-strength fiber material.

PHASE II: Scale the production method(s) to limited mass production, finalize the manufacturing process outlined in Phase I, and refine the process to optimize throughput for a given set of fiber properties. Experiments will be conducted to determine the strength and toughness of the fibers and compare them to those of existing high-strength materials. Detailed cost analysis and a cost comparison with existing high-strength materials must be provided for all developed materials. Evidence must also be provided that the resulting fibers and fabrics exceed the strength and toughness of current commercially available materials. Samples of fibers and fabrics should be provided to test potential performance enhancements to the U.S. Army protective structures.

PHASE III Dual Use Applications: Scale the production method(s) to mass-produce commercially viable CNT-based fiber products. CNT-based fibers have potential commercial and military application for high-strength fibers, fabrics, and reinforcement material in a wide range of high-performance composites.

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KEYWORDS: executive, advanced manufacturing, nanofibers, nanotubes, woven fabric, tensile strength, elastic modulus, toughness

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A12a-T027 TITLE: <u>Development of a Subunit Vaccine for Prevention of Diseases Caused by Streptococcus Pyogenes Infection</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To develop a subunit vaccine for control of infections caused by Group A streptococci, to include formulations, safety and potency in pre-clinical models.

DESCRIPTION: The importance of infections caused by the bacterium Streptococcus pyogenes (Lancefield Group A streptococcus) within the US military has long been recognized, and outbreaks with considerable morbidity still occur. S. pyogenes is a perennial human pathogen, causing infections and life-threatening diseases including pharyngitis, impetigo, necrotizing fasciitis, streptococcal toxic shock syndrome and rheumatic heart disease. This pathogen is a common cause of wound and trauma-associated infections. Antibiotic-resistant strains are increasing in global distribution, and a marked worldwide increase in the prevalence of serious invasive disease caused by S. pyogenes has occurred in the last two decades, perhaps due to the emergence and distribution of more virulent strains. Although the incident is low, the recorded overall mortality rate is 45% among streptococcal toxic shock-like syndrome cases. There are currently no licensed vaccines available for protection against diseases caused by S. pyogenes. Ideally, a vaccine should incorporate antigens from a major virulence determinant or antigens that are ubiquitously expressed by disparate bacterial strains. Recently a vaccine was developed (US Patent 7,087,235) based on a recombinant protein fusion between genetically inactivated subunits of streptococcal pyrogenic exotoxin B (SpeB), a cysteinyl protease expressed by all clinical isolates, and streptococcal pyrogenic exotoxin A (SpeA), a superantigen produced by many isolates. The SpeAB vaccine was effective at protecting mice from lethal bacterial sepsis and toxic shock syndrome.

PHASE I: Phase I work will focus on optimization of a vaccine formulation incorporating the SpeAB protein for potency and stability. Data obtained in phase I will determine which assays are suitable to evaluate the stability of the formulation as well as which vaccine excipients provide the greatest enhancement of stability. Potential for contributing innovation in manufacturing of vaccines intended for human use.

PHASE II: Based on Phase I results, Phase II will demonstrate safety and potency in pre-clinical safety studies. A data package required for a FDA approval pathway will be assembled, and a path forward to clinical evaluation of the vaccine will be outlined.

PHASE III Dual Use Applications: Clinical evaluation for Department of Defense and/or commercial applications of the subunit vaccine for prevention of diseases caused by Streptococcus pyogenes infections.

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KEYWORDS: vaccine, Group A streptococcus, Streptococcus pyogenes, potency, stability, formulation, wound infection, burn infection, respiratory infection, Manufacturing-related

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A12a-T028 TITLE: DNA Vaccine Technology to Rapidly Produce Cocktails of Polyclonal Antibodies to Neutralize Lethal Viruses of Military Importance

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Demonstrate that an industrial partner can use existing DNA vaccines to produce large quantities of a polyclonal antibody-based product that is 1) as non-reactogenic as currently licensed polyclonal antibody products produced in horses and sheep, and 2) protective when used as a post-exposure prophylactic to prevent lethal viral hemorrhagic fever in an animal model.

DESCRIPTION: The Army, Department of Defense, and nation require the development of capabilities to rapidly respond to naturally emerging infectious diseases, and diseases caused by organisms intentionally used as weapons. Viral hemorrhagic fevers are caused, primarily, by viruses in the Filoviridae, Arenaviridae, and Bunyaviridae families. These diseases are highly lethal, can spread person-to-person, and are difficult to treat. There is no anti-viral drug licensed by the FDA for any viral hemorrhagic fever. These diseases are rare and the development of medical countermeasures (MCM) is not market driven.

MCM to treat other rare but lethal diseases have been developed. Often these products consist of polyclonal antibodies. For example, antivenoms are used to prevent death caused by the bites and stings of venomous animals (e.g., snakes, spiders). Anti-toxins are used to treat rare intoxications, such as botulism poisoning. Rare viral diseases such as rabies or complications associated with smallpox vaccination are also treated by the use of polyclonal antibodies (e.g., Rabies Immune Globulin, Vaccinia Immune Globulin [VIG]). Most of these polyclonal antibody-based products for rare diseases are produced from pools of plasma collected from volunteers immunized with a licensed vaccine, or from chemically despeciated antibodies collected from vaccinated horses or sheep.

Antibodies have been shown to protect against Filoviruses, Arenaviruses, and Bunyaviruses in the laboratory. Nevertheless, developing polyclonal antibody cocktails as products for viral hemorrhagic fevers is hampered for several reasons. First, there are few survivors of these diseases, so a natural source of anti-sera is not available. Moreover, for some viral hemorrhagic fevers (e.g., Ebola), even the serum from survivors has only weak neutralizing activity. Second, there are no FDA approved vaccines for these diseases, so anti-sera cannot be collected from vaccine recipients. Even if sera from human volunteers were available, its safety, potency, and consistency would be difficult to control and evaluate. Human-tissue derived products must go through extensive inactivation protocols to remove pathogens. Third, experimental vaccines against some viral hemorrhagic fevers have not produced high-titer neutralizing/protective antibodies. Modifications of the target immunogens, adjuvants, or delivery systems might be required to produce high-titer neutralizing antibodies.

The Military Infectious Disease Research Program (MIDRP) in collaboration with Chemical-Biological Medical Systems (CBMS) funded partners performed basic research that demonstrated the feasibility of using DNA vaccine technology to produce high-titer neutralizing antibodies against hantaviruses and arenaviruses in animals (1, 2, and unpublished). The hantavirus polyclonal antibodies were protective when used as post-exposure prophylactics in an animal model of lethal hantavirus pulmonary syndrome (3). More recently, we demonstrated that antibodies produced in DNA-vaccinated ducks and purified from duck eggs were capable of protecting hamsters against lethal infection with a hantavirus (unpublished). These duck antibodies are naturally lacking the reactogenic fragment of the antibodies. In order to transition this technology to a product suitable for human use, we solicit an industrial partner to demonstrate that they can use DNA vaccines to produce large quantities of an antibody-based product that is as non-reactogenic as currently licensed polyclonal antibody products produced in horses and sheep, and that the product can be used as a post-exposure prophylactic to prevent lethal viral hemorrhagic fever in an animal model. If successful, this project could lead to the commercialization of a capacity for rapid production of polyclonal antibody-based medical countermeasures to prevent and treat emerging infectious diseases (e.g., hantavirus pulmonary syndrome, Argentine hemorrhagic fever, Bolivian hemorrhagic fever, Venezuelan hemorrhagic fever, Brazilian hemorrhagic fever, hemorrhagic fever caused by Ebola virus and Marburg virus), treat intoxication (e.g., anthrax and botulinum intoxication), and also to replace antiquated products produced from human blood (e.g., VIG).

PHASE I: Demonstrate proof-of-concept that it is possible to use DNA vaccine technology to rapidly produce naturally despeciated polyclonal antibodies in animals, purify the antibodies, and demonstrate the material is capable of protecting animals against viral hemorrhagic fever when administered postexposure.

PHASE II: Move this technology beyond proof-of-concept towards commercialization. Optimize production and scale-up processes. More importantly, evaluation of the reactogenicity of the polyclonal antibody product needs to be evaluated, possibly using a system that mimics the human immune system.

PHASE III DUAL USE APPLICATIONS: If this system is successfully developed and tested, then it will be possible for the industrial partner to rapidly manufacture human-safe polyclonal antibodies for essentially any infectious disease that can be prevented or treated using neutralizing antibodies.

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KEYWORDS: DNA vaccine, polyclonal antibody, postexposure prophylactic, viruses, protection, manufacturing, advanced

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A12a-T029 TITLE: Naturalistic Neurocognitive Assessment Using Mobile Gaming Platforms

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: To develop, pilot, and deploy a mobile gaming platform that permits assessment and monitoring of reaction time and attention among military service members with conditions that impair these cognitive functions.

DESCRIPTION: Neurocognitive health affects the function and quality of life of military service members and their families and is critical to force readiness. Assessing and monitoring neurocognitive health is particularly relevant for supporting service members given the increased rates of traumatic brain injury (TBI) and psychological health problems (including sleep deprivation, substance use, mood and anxiety disorders, and pain conditions, among others) experienced by military service members.

Current practices for assessing and monitoring a service member's cognitive status are event-triggered (i.e., blast exposure, performance problems), and involve screening with neurocognitive assessment tools (NCATs) followed by more extensive clinical evaluation and NCAT administration. The administration of currently available NCATs is often time-consuming, obtrusive, and undertaken in a clinical, rather than a naturalistic, environment. Additionally, NCAT administration is formalized and structured in a manner that presents challenges to practical, rapid, and/or serial assessment.

Mobile devices (e.g., smart phones, mp3 players, portable game devices) and their software applications (apps) are in widespread use in military and civilian populations. The availability and acceptance of these technologies presents an opportunity for the development of NCATs designed specifically for administration using these platforms.

Highly-engaging and enjoyable gaming apps can be designed to gather neurocognitive data (e.g., reaction time, sustained attention, divided attention, declarative memory, procedural memory, problem solving and other executive function) while being played. This method of neurocognitive assessment and monitoring presents several theoretical advantages over current practices. First, an NCAT of this type travels with the service member and therefore is readily deployable whenever it is needed. Second, these devices are familiar to most service members, and most are reasonably facile with their use; this reduces the likelihood of assessment error stemming from testing on an unfamiliar or novel technology. Third, the app on which testing is performed a relatively short time period and unobtrusively is not experienced by the service member as a 'test' but instead as a game; this offers the potential of reducing test anxiety-related performance problems and increasing the service members engagement in, and enthusiasm for, participating in this assessment. Fourth, testing using this type of NCAT is performed in the environment in which the service member must perform his or her duties taking into; it does not attempt to eliminate sources of distraction or intrusion into the service member's performance, but instead assesses it in the context of a person's environment to better approximate "real world" performance. Finally, the game can be designed in a manner that allows the service member's performance baseline to be established easily, reassessed serially, and communicated readily easily via routine device synchronization to healthcare providers and others charged with evaluating the service member's neurocognitive health.

The objective of this STTR (Small Business Technology Transfer) is to solicit concepts for the development of a mobile device based game that provides this type of neurocogntive assessment and monitoring. For the present STTR, the game will be designed to assess reaction time and attention. These cognitive domains are highly sensitive to disruption by a wide range of military health-relevant conditions, including TBI, PTSD, substance intoxication and/or withdrawal, pain, sleep deprivation, and fatigue. The use of mobile devices that are currently available and the adaptation of popular gaming apps to this purpose is encouraged, and will facilitate the distribution and adoption of this type of NCAT.

PHASE I: Conceptualize, design, and build a solution for a cell-phone gaming platform that provides ongoing assessment and monitoring of the reaction time and attention. Required Phase I deliverables will include: research design; prototype with limited testing in demonstrating proof-of-concept in vitro including performance metrics such as accuracy and sensitivity in measuring attention and reaction time, demonstration of clinical interface; research plans for preclinical testing; and commercialization strategy including regulatory plans. The solution should include ability to have information gathered by the platform to be easily reviewed and obtained both by the patient and treatment provider(s). Literature and market review should be done as part of the proposal background information and not as a task to be executed during Phase I period. Although it is anticipate that in vitro testing and consultation form subject matter experts will occur there should be no formal human use testing proposed or executed during this 6-month Phase I period due to requirement of second level DoD (Department of Defense) review, which generally adds more time beyond the 6-month Phase I period.

PHASE II: Assess the proposed solution in a demonstration trial to examine feasibility, as well as initial efficacy and utility of the platform. The trial should be designed to compare the proposed solution with standardized and widely accepted NCAT testing procedures. The population used for the trial should include a healthy comparison group with military relevance along with group(s) of subjects with reaction time and attention impairments (e.g., attention-deficit hyperactivity disorder, moderate-to-severe TBI, acute intoxications, sleep deprivation). Testing in these populations should demonstrate the solution's ability to identify reaction time and attention impairments.

PHASE III Dual Use Applications: Phase III efforts should be focused towards technology transition, preferably commercialization of STTR research and development. This should include assisting the military in transitioning the technology to widespread deployment and use as well as plans to secure funding from non-STTR/SBIR government sources and /or the private sector to develop or transition the prototype into a viable product for sale in the public and/or private sector markets.

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KEYWORDS: Attention, reaction time, processing speed, cognition, mobile device, applications, gaming

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A12a-T030 TITLE: Landmark Navigation for Unmanned Ground Vehicles

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: The objective is to develop a system for controlling or guiding an unmanned ground vehicle (UGV) in challenging communication environments through the identification and tracking of visual landmarks in still images.

DESCRIPTION: Fielded robotic systems typically operate in relatively clear line-of-sight situations. This topic seeks control solutions for non-line-of-sight teleoperation with degraded communications, such as might occur when teleoperating a robot deep within a building or cave. The topic is not soliciting for improvements to communications technology, but in control mechanisms that will work with existing radio hardware. We assume that the environment is sufficiently complex such that full autonomy is infeasible and human assistance is required. It is also assumed that tethered operation is impractical and that a communications infrastructure cannot be placed. It is envisioned that low frequency radios and/or a set of communication relays will be required to establish a communications link. It is assumed that either of these will result in a communications channel that is noisy and has low bandwidth and high latency. Under these conditions, it is expected that direct teleoperation would be very challenging.

Assuming that a communications link can be established, this topic is exploring the potential for controlling or guiding the robot via landmarks extracted from a series of still images captured from on-board cameras on the robot. The operator will indicate the navigation path, waypoints, or an object to manipulate on the Operator Control Unit (OCU) displaying the images from the robot. The system will need to make and maintain a correspondence between the path, waypoints or objects indicated on the OCU and the selected visual landmarks. The robot needs to track the landmarks, and perhaps acquire new ones, as it navigates the desired path to the end point.

Indoor environments can be challenging for finding good visual features and therefore, a key part of the research will involve finding good image features that can be used as visual landmarks, which have the properties of being stable over time and recognizable from many locations. Commonly used image features in computer vision include: Shape Invariant Feature Transform (SIFT), Speeded Up Robust Feature (SURF), and various corner detectors, such as Harris and SUSAN (Smallest Univalue Segment Assimilating Nucleus). The RANSAC (RANdom SAmple Consensus) algorithm is often used to provide robust estimation of model parameters and to remove outliers. This topic is seeking advancements over these standard techniques for feature selection, as well as associated robust feature tracking algorithms. Comparing the features selected by the algorithm to those that an animal or human might choose to be good visual landmarks may be useful, since humans and many animals have good image segmentation capabilities that allow rapid object recognition and assignment of robust visual landmarks.

The topic is looking for algorithms that operate on imagery from electro-optical sensors, such as visual and infrared wavelengths. While a final UGV implementation may include additional sensors for obstacle detection and avoidance, the system developed under this topic should utilize a single camera. There are a number of research efforts on bearing-only navigation, which does not require accurate range sensing. The robotic platform is expected to be 20 – 200 kg, but the system should be applicable to larger vehicles. The system should handle vehicle speeds up to 20 kph. It is expected that the operator will choose reasonably safe paths for the vehicle to navigate. The system will require intuitive methods for the operator to indicate the desired path, objects to manipulate, and desired camera positions. Commanding and following paths around corners and behind obstacles can be challenging.

PHASE I: The first phase consists of investigating feature extraction algorithms, developing a preliminary design for the OCU and sensor package, and providing analysis of potential communication systems that permit sufficient connectivity and that would be suitable for a small robot. Feasibility of the proposed approach should be demonstrated through simulation or implementation. A final report documenting the activities in the project will be delivered.

PHASE II: The second phase consists of a final design and full implementation of the system. At the end of the contract, landmark-based navigation shall be demonstrated by controlling a robot in a degraded communications environment. Deliverables shall include the prototype system and a final report, which shall contain documentation of all activities in this project and a user's guide and technical specifications for the prototype system.

PHASE III DUAL USE APPLICATIONS: Commercial opportunities include UGV applications that may require operation with degraded communications, such as civilian search and rescue, and fire fighting, along with military applications in surveillance and reconnaissance. Additionally, this research has application for controlling multiple robots, or controlling robots through the Internet or via cell phone.

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5) http://www.asl.ethz.ch/people/lium/personal/icra10 (A Bearing-Only 2D/3D-Homing Method under a Visual Servoing Framework)

6) http://staff.frederick.ac.cy/eng.lsg/Papers/ants_inspired1.pdf (Biologically Inspired Bearing-Only Navigation and Tracking)

KEYWORDS: robot, teleoperation, visual servoing, landmark, bearing-only, navigation, latency

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